VSVI· CIVIVM: DECORI VRBIVM

SESSIONAL PAPERS

OF THE

ROYAL INSTITUTE OF BRITISH ARCHITECTS.

Incorporated in the Seventh Year of William IV.

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PATRON—HIS ROYAL HIGHNESS THE PRINCE OF WALES, K.G., &c.

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PAPERS

READ AT THE

Royal Institute of British Architects.

SESSION 1871-72.

USUI CIVIUM, DECORI URBIUM.

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ERRATUM.

Mr. W. H. King, Secretary to the Essex Archæological Society, has forwarded the following note in reference to his observation (erroneously attributed to Mr. C. R. King, Associate) in the discussion on Eastbury Manor House, p. 172:—

> "I have no doubt that the builder of 'Porters,' in Essex, was Humphrey Browne, who by Will, dated 30th August, and proved 5th October, 1592, describes himself as 'of Porters, in the parish of Prittlewell, Gent.,' and 'late Citizen of London.' I am inclined to think that the house was built but a few years prior to that year, and that circa 1585 will be an approximate date; the manner in which he subscribes himself as above stated, would seem to show that he had not long retired from business, having probably acquired a fortune, bought the estate which is rather small, and as I suppose erected the residence thereon. He was probably not very old, as he left eight children all apparently minors. Norden, in his Survey of Essex, 1594, writing of Porters, describes it as 'Brownes,' and marks it on his map. Mr. James Heygate is the present owner of the property."
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> * * * * *
>
> "I notice one other error with regard to myself. What I said was, that the wall paintings were *not* frescoes, I never thought them other than distemper paintings."
>
> "W. H. K."

Erratum—On p. 141, for 'p. 80,' read 'p. 136.'

for myself, had my health permitted me to do so.

"Believe me,

"Yours very truly,

"WILLIAM TITE."

"C. L. Eastlake, Esq.

B

Royal Institute of British Architects.

SESSION 1871-72.

At the Opening General Meeting of the Royal Institute of British Architects, held on Monday, November 6th, 1871, THOMAS H. WYATT, President, in the Chair.

PRELIMINARY PROCEEDINGS.

PRESENTATION OF SIR WILLIAM TITE'S PORTRAIT.

After the transaction of the usual routine business, the PRESIDENT read the following communication from Sir William Tite:—

(Copy.) "*Pavilion, Folkestone, November 2nd*, 1871.

"MY DEAR MR. EASTLAKE,

"I am greatly obliged to the Council for the suggestion, and to you for communicating the fact that my Portrait, painted by my friend Mr. Knight, is to be formally presented to the Institute on Monday evening next, and at a special meeting. I hope I may say I am a good deal better for my long stay here; but I feel I am bound to remain as long as I can to shorten the London winter. We propose to return to town on Monday; but as evening hours are now quite impossible to me, I must decline, though with much regret, the pleasure of joining you at the presentation. Will you ask the President, on that occasion, to address my especial thanks to those friends of mine who originated and carried through the subscription for the portrait itself, and at the same time let me express to the President, the Council, and in fact every member of the Institute, my warm and very sincere acknowledgments for the support they have ever given me during the five years of my presidency, and at all other times since we have been in any way connected.

"I am sorry to be obliged to trouble another to say for me, what I would so gladly have said for myself, had my health permitted me to do so.

"Believe me,

"Yours very truly,

"C. L. EASTLAKE, Esq. "WILLIAM TITE."

THE PRESIDENT then requested Professor Kerr, who had kindly taken charge of the subscriptions and the arrangements connected with the portrait, which was exhibited in the room this evening, to make a few words of explanation in remarks on the subject.

PROFESSOR KERR, Fellow, said, he thought all he need say this evening might take the form of information as to the circumstances which had resulted in the presentation of this portrait to the Institute. He hoped the meeting would consider the portrait as being formally presented by the President: he (Prof. Kerr), as Treasurer of the Fund, had merely to give a brief account of his stewardship. About three years ago, Sir W. Tite, then President of the Institute, having always acted most liberally towards the Institute, was kind enough to give a considerable sum of money for the purchase of certain books for the Library. It was at that time considered that the occasion was a good one to pay Sir William a compliment of this kind, and it was proposed that his portrait should be painted and presented to the Institute, by the ordinary mode of subscription amongst the members. Those by whom the proposal was made, were good enough to entrust him (Prof. Kerr) with the collection of the subscriptions, it being understood that they should be limited to one guinea. He at once received promises of subscriptions, amounting to nearly the whole of the sum required. He had received payments amounting to 64 guineas, of which 50 guineas had been paid on account to the artist. The cost of the portrait was 100 Guineas: the frame and expenses of collection he had to ask them to accept as his own contribution, in a peculiar way, which he would ask a moment to explain. He had felt that the Voluntary Examinations of this Institute should be conducted without the expense of fees to the Examiners; and as he had lately received the sum of 10 Guineas for acting as an Examiner, he asked permission to appropriate that money in payment for the frame of this portrait, and the cost of circulars; and the balance he would hand over to the fund for the portraits of Professor Donaldson and Mr. Beresford Hope. For the net amount of 100 guineas thus required he had already eighty-five subscribers, and he felt certain that his list would be augmented before the meeting broke up. Sir William Tite had, as they all knew, been a great friend to the Institute, and those who subscribed to this testimonial of respect and esteem did so, in compliment not only to a past President, but to a most distinguished architect, who was an honour to the profession in various ways. He was proud in having been an humble instrument in the collection of the subscriptions, and he was quite sure he had only now to lay the list on the table to obtain the completion of the transaction.

Mr. G. GODWIN, Fellow, said, as a subscriber, he would take the liberty of expressing his great satisfaction with the portrait. In addition to its being an excellent likeness, Mr. Knight had produced a very good picture.

SIR DIGBY WYATT, Fellow, suggested that the names of the persons represented in these pictures, as also those of the artists, should be inscribed upon them: because, though the present generation of members might know all the circumstances connected with them, those who succeeded them might not do so.

The President then proceeded to deliver his Address.

OPENING ADDRESS FOR THE SESSION 1871-72.

GENTLEMEN,—It seemed an essential part of my duty to address you so frequently during the last session, that I am sure you must have been tired of the sound of my voice; and I would now gladly have resumed the ordinary work of the Institute, without again trespassing on your attention and on your patience, but I am told on official authority, that it is "*de rigeur*" for your President to open the Session with some remarks on the past and present condition of the Institute, and on passing events of interest to the Members. I therefore set my own feelings aside and at once proceed to business.

Gentlemen, we meet once again for work, after an autumnal recess and holiday, which I trust has been refreshing and instructive to all those who have been fortunate enough to get away from their offices. Some I know have been unable to do so: myself amongst the number, and we can only seek your pity.

I was much amused the other day with an article in a well-known weekly paper, on "Getting into Harness," a portion of which I cannot resist quoting, for many will recognize its accuracy. "There is "a dismal process which many of our readers are probably enduring at the present moment, and to "which most of them will perhaps be subjected within a very short period. They have been *out at* "*grass*, and are being returned to the stable. They are groaning in spirit, as the harness once more "presses on the old places, and it may be, finds out old sores that have scarcely had time to get them-"selves decently skinned over. They wince and plunge and feel restive, but they are conscious that "their struggles are useless, and that in a very few days they will be plodding the old weary mill round "in the old weary spirit. At such moments one is subject to a temporary doubt, whether the brief "period of relaxation is on the whole a blessing or a curse!" As in all things, however, consolation is to be found; we who have been condemned to the uninterrupted "old weary mill round" are at least spared the necessity of a decision on this temporary doubt, and can enjoy the "groanings" and "wincings" of our more fortunate travelled brethren for whom there is no escape.

Gentlemen, when we opened our last Session our numbers stood as follows:—

Fellows	275
Associates	235
And Students	7

The total number, including all classes—625.

At the present moment, our numbers stand thus:—

Fellows	276
Associates	243
Students	21

And in all classes—644.

I take this opportunity of observing that there are many Associates of the Institute, whose age and professional status would fully justify their presenting themselves for election as Fellows. I trust that those who can do so conformably with the conditions of our Charter, will not hesitate to submit their names for that purpose. I would further suggest that those younger Architects, who are pupils or assistants of Members of the Institute, should be encouraged to join the ranks of our Associates. We all must bear in mind, that in a corporate society such as this, numerical strength is one mode of ensuring professional unity and the maintenance of that "*esprit de corps*," which I trust will always find support within these walls.

With regard to the very limited number of Students at present on our books, I believe it may be attributed to the energetic efforts being made by other societies in the cause of architectural education,

and to the increased opportunities for study and improvement now offered to the student in architecture, rather than to any indifference on their part, that our numbers appear so small. We find a large number of young men members of the "Architectural Association," where their opportunities for improvement are very great; and we have the Royal Academy now aiding in this good work, under the charge of Mr. Phené Spiers.

There are Architectural Classes at "King's College" and at the "London University," under the guidance of able professors; we have, in union with the Architectural Association and with the Architectural Museum, Architectural Art Classes, especially for the benefit of the student, where lectures and lessons in training are superintended gratuitously by some of the ablest members of our profession. The student of the present day cannot then complain of indifference to his progress, or want of opportunities for professional improvement.

The "Voluntary Examination" does not, I fear, make the progress that has been anticipated for them by some of us. During the past session no candidate has applied for admission in the Class of Proficiency, or in that of Distinction; but for the "Preliminary Class," eleven candidates offered themselves for examination, of whom ten passed. We are yet in the early days of this experiment, and it would be unwise to express any decided opinion on the ultimate result. At present, however, the cost of the examination is heavily disproportionate to the result obtained, so much so, that the Institute is, in my opinion, certainly not justified in holding it oftener than was originally arranged, viz., once in every two years. Should the Conference also become biennial, it will, perhaps, be found convenient to let it alternate from year to year with the examination.

The Annual Accounts of the Institute being made up at Christmas, I can only give a statement of the Receipts and Expenditure for 1870, as compared with 1869, they stand thus:—

1869.				1870.			
Balance from 1868	£86	13	6	Balance from 1869	£133	2	4
Receipts	1865	5	11	Receipts	1770	2	8
	1951	19	5		1903	5	0
Expenditure	1434	17	1	Expenditure	1634	19	1
Balance	£517	2	4	Balance	£268	5	11
Of which £384. was invested.				Of which £198. 12*s*. 9*d*. was invested.			

The receipts for 1870 include another generous contribution of £100. from Sir William Tite, C.B., to the Travelling Fund. A sum of £42. was received as composition for annual subscriptions, and duly invested. In the same year £111. 8*s*. 8*d*. was expended upon the Voluntary Architectural Examination; and a donation of £50. was given to the "Architectural Art Classes." The Annual Report of our Council issued last May will have informed you of other details in connection with the state of our finances.

Since I had to address you at the opening meeting of last year, we have lost three Fellows— Mr. Hardwick, R.A., Sir James Pennethorne, and Mr. Charlesworth of Manchester; and two of our Honorary and Corresponding Members, viz.—Monsieur Duban, of Paris, and Signor Ignazio Gardella, of Genoa, have passed away.

Of Mr. Hardwick I can but speak with much personal regard. He was my master: I spent four years with him as a pupil while he was engaged on the St. Katharine's Docks and the Goldsmiths' Hall; and if, at that time, the opportunities for studying the artistic part of his profession were hardly within

reach of the architectural pupil (instead of being sown broad-cast before him, as they are in the present day), I had at least the opportunity of seeing and studying most abundantly the practical part of my profession; and I never can feel sufficiently grateful for the habits of business and of punctuality which he inculcated, and for his constant teaching, as to the high position our profession should occupy, and the necessity for an honorable and unswerving line of conduct in all who followed it. The architectural publications of the day have so well described Mr. Hardwick's professional position, his works and his appointments, that I need only bear my testimony to their accuracy, and repeat these words from one of those papers as faithfully describing his character: "Personally, Mr. Hardwick, notwithstanding severe "indisposition of a very painful kind, was active and energetic. He had a generous, quick nature; and "there are many now recollecting good deeds and kind assistance rendered in a very unostentatious and "hearty manner, of which the world suspects little. He was a man who personally merited the whole "of that very general confidence which was placed in him by persons of all stations; and his cultivated "intelligence, his high sense of honour, and his upright straightforward conduct, have done not a little "to reflect credit upon the profession to which he was proud to belong."

Gentlemen, this time last year, I could not resist the opportunity of paying my meed of praise to the skill with which the late Sir James Pennethorne had carried out the "London University," in Burlington Street: I ventured to foreshadow the honour which was subsequently bestowed upon him by his Sovereign; and I expressed an earnest and sincere hope, that he might long live to enjoy his repose and his laurels. That wish has not been realized! and this able, kind-hearted, and unassuming architect, has passed away from us as tranquilly and peacefully as his life had been spent. I rejoice to think that this Institute had publicly borne its testimony to his merit and his high character, by presenting to him not only the Queen's gold medal, but a special medal "to mark their sense of his "ability, courtesy and frankness, and of the skill and intelligence he habitually brought to bear upon "complicated and difficult questions of a technical nature." It must be a source of pride and solace to his family to remember how he was honoured by his Sovereign and by his profession, and esteemed by all who knew him. The architectural journals of September describe fully his career and his works. I think I may promise that a memoir of each of these distinguished architects will, ere long, be read at the Institute, and I venture to say, "*Requiescant in pace.*"

Mr. Charlesworth, of Manchester, died comparatively young, having been born in 1832. He was a pupil of Mr. Isaac Holden, and when a youth but twenty years of age, he entered the office of Mr. Speakman, whose partner he became in 1862. In conjunction with that gentleman he executed the following works—St. Catherine's Church and Schools, Collyhurst, St. Paul's Church, Southport, the Manchester Shipping Offices, the Clarendon Club, the Mansfield and Bow Chambers, &c. He had remarkable facility as a designer of Italian work specially; and many of the warehouses in Manchester, and mansions in the neighbourhood, attest his powers as an artist, and show a remarkable amount of invention and refinement. As a Gothic architect, his work, though excellent, was perhaps not so original. The design submitted by Mr. Charlesworth, with his partner, Mr. Speakman, took the second prize in the competition for the Manchester Town Hall.

Monsieur Duban, of Paris, one of our Honorary and Corresponding Members, died at Bordeaux, in September last year, when the cloud of misfortune and discomfiture was hanging so densely over his country. Her subsequent troubles have prevented, until lately, the removal of his body to Paris, and a complimentary funeral, which his architectural friends and confrères in that city were anxious to realize. That wish has, however, been accomplished, apparently with every success, and I cannot do better than read to you a very interesting letter which Professor Donaldson has done me the honour, as your President, to address me. It clearly describes the interesting though melancholy ceremony.

"*Nice*, 14*th September*, 1871.

"MR. PRESIDENT,

"I regret that from various circumstances with which I need not trouble you, I have been prevented giving you the details of the ceremony which took place this day week in Paris, in connection with the lamented death of our Honorary and Corresponding Member Mons. Duban, at Bordeaux, last year, and the anniversary of which has been observed with great funeral pomp, and the transfer of his body to the 'Cemetière du Mont Parnasse,' near the Invalides. You are aware of the invitation sent by Mons. César Daly for Members of the Institute to be present, and in consequence Mr. George Alexander and myself arranged to go over, and I observed there also Mr. Phené Spiers. The service took place at the Church of St. Thomas Aquinas, the Monastery of which has for a long time been occupied by the fine Museum of Artillery. I was appointed to be one of the pall bearers, with Messrs. César Daly, Duc, Leon Vaudoyer, and Baltard (Hon. and Corresponding Members of our Institute), and other friends of the family. Mr. Alexander was, with great courtesy, seated in a prominent place amongst the general mourners. The mass was conducted with music, and then the cortége left and proceeded to the cemetery, the body on a hearse, and the pall bearers on foot, and four carriages with various members of the family and mourners. Arrived at the tomb, a short conclusion of the service, similar to ours, was read by the priest, and the coffin deposited in the tomb, which, however, is merely provisional, as it is intended to erect a more important one. After the priests had retired, MM. César Daly, Baltard and Vaudoyer, read very appropriate discourses, reviewing the talents, personal character and works of the deceased, now and then diverging into observations upon the present state of our art in France, which they seemed to consider as not satisfactory; and deploring the introduction of a wild caprice of style, the absence of a sound leading principle of taste, and the prevalence of too luxurious, ill-regulated decoration. When these were com pleted, I claimed permission to say a few words, conveying expressions of sympathy on the part of the Royal Institute of British Architects, and the desire of our members to show how sincerely they took part in the loss, which the French School of Art in France has sustained, as well as all Europe; and I ventured to express the conviction, that amongst the distinguished pupils of our late friend, and the eminent architects who survived him, there were men who would well sustain the prestige of their school of our art amongst the nations of Europe. My few expressions seemed to impress with lively satisfaction those who were present; and many pressed round me to shake hands and thank me for the interest taken by English architects in the loss of their eminent colleague.

"Two days afterwards, Mons. César Daly and four other gentlemen, members of the committee who directed the funeral ceremony, called on us at our hotel, formally to express their satisfaction at the kindness of the English architects. Mons. Daly also read to us the very well conceived letter, which he had just received from you, and said that they had all been highly gratified by that mark of kind consideration from the President of the Royal Institute of British Architects. All the proceedings, discourses, and letters, are being collected into a separate memoir; thirty copies of which will be sent for distribution amongst the Members of Council, &c.

"Having to pass through Marseilles, I have of course called upon our venerable friend Mons. Coste, (one of our Hon. and Corresponding Members). He is now more than 84, with his usual vivacity of spirit, love of art and desire to maintain all his old friendships. He took a ride with me round Marseilles, and particularly made me visit the grand Musée of Fine Arts and Natural History, by Mons. Esperant-Dieu, a pupil of Mons. Vaudoyer, who has also built the striking church of 'Notre Dame de la Garde.'

"The Musée is backed against a rocky hill, which has been cut away to receive it. It consists of two wings, the one for the Fine Arts, the other for the 'Natural History.' They are connected (being perhaps 150 ft. apart) by a receding circular colonnade on the first floor, having a central pavilion with a statue of Marseilles, and a large basin in front, the overflowing waters of which fall down on rocks or steps (like those of St. Cloud) to the very base, where there is a garden, with beds of flowers and trees. I think this is one of the most scenic compositions that I know in Europe. Mons. Coste has promised to ask Mons. Esperant-Dieu to send us photographs of his works; for I am sure that the Institute would be glad to elect him into their body.

"I also engaged Mons. Coste to draw up for us a paper on the Turkish Mosque, distinguishing the peculiar arrangement and parts of those at Constantinople (formed upon a Byzantine type)—those at Cairo and Damascus being purely Arabian, and having also their individual dispositions for pilgrims, &c. He seems highly delighted with the idea, to which he above all men is so capable of doing full justice; and I have no doubt he will set about it, and it will be a very interesting contribution for our Transactions. He asked very particularly for his old friend and fellow-traveller in Egypt, I. Bonomi, and was glad to hear of his being in good health, and that I was connected with him at the Soane Museum.

"I hope you will not be fatigued by my too long details of what has occurred, but such an incident as the funeral of Mons. Duban is a rare occasion, the only like one being when Mons. Fontaine was buried, and when I also said a few words. I have thought that it would interest you and the Members to know what took place.

"Believe me, dear Mr. President,

"Very faithfully yours,

"THOS. L. DONALDSON."

Gentlemen, I have sought to give some interest to my otherwise dull record of our proceedings, by grafting upon it, and making part and parcel of it this very interesting communication from our valued friend and colleague. Independently of the clear description it gives of a ceremony that must always have a melancholy interest, and which at this moment must have a special one, as indicating a sort of coming to life again of our intellectual and accomplished French confrères, it has a peculiar value in my eyes, for it leads me to hope and believe that the temporary dissatisfaction which Professor Donaldson felt with regard some of our proceedings during the last session has passed away: that he now acquits me of having for a moment contemplated a slight to him, and that we may hope for a revival of that pride and interest in the Institute which for so many years he has shewn without stint.

Our Hon. Secretary for Foreign Correspondence, Mr. Cockerell, (who I am happy to think is fast recovering from a very severe illness), will, no doubt, at no distant period, prepare a paper on Mons. Duban's life and works. I shall only remark that the Architect of the façades of the "Beaux Arts" (especially the old one), of the restorations of the Château de Blois, and originally of the Sainte Chapelle, of the house of the Count of Pourtalès, in the Rue Tronchet, of the works for the Duc de Luynes, at his Château at Chevreuse, should always hold a high place in our esteem. His public professional position was not as high as it should have been; politically he was not fortunate: he opposed Napoleon the Third when President of the Republic, and on his succeeding to the throne Mons. Duban was dismissed from his position as Architect to the Louvre, and from the superintendence of the works on the Southern façade, which were then under his charge, but the Salon Carré and some of the other important rooms in the Louvre were also works of M. Duban.

Signor Ignazio Gardella, elected an Hon. and Corresponding Member of the Institute in 1856, was President of the Society of Engineers and Architects at Genoa, where as Architect to the Municipality he carried out several important works, including the Docks and Chamber of Commerce. He was also an Associate of the Academies of Florence and Genoa.

I ventured last year to call the attention of members, to the importance of aiding the Council by contributing Papers for our Ordinary Meetings; and I reminded them of the bye law which bears on this point, and imposes a duty on all new members of contributing a paper, or making a donation to the library fund. A very fair response was made to this appeal; several interesting papers were read, leading to useful discussion, and donations to the amount of £94. were received. Amongst the most valuable papers may be mentioned those of Professor Ansted, 'On the Selection of Building Sites;' 'On St. Thomas's Hospital,' by Mr. Currey; 'On the Roof of St. Pancras Station,' by Mr. Barlow; 'On the Mathematical Theory of Dome Construction,' by E. Beckett Denison, Esq.; 'On the Decoration of St. Paul's Cathedral,' by Mr. Penrose; and 'On Cistercian Architecture,' by Mr. Sharpe. The Committee who have kindly undertaken to procure and select papers, have already received promises of several for the early part of this session, but they request me to renew my appeal for further contributions of this kind.

Gentlemen, I need hardly remind you of the change that took place last session in our secretarial offices and arrangements; and most assuredly, I would say nothing that could revive any controversial feelings; but, as one who had to bear a large share of the obloquy which in some quarters was thought to attach to this act, I think I may, in justice to myself, appeal to the members present, and ask if the Institute has lost in energy and usefulness by the change; or if, individually, members have received less courtesy and assistance from the officials of our Society under the new *régime* than they did under the old?

I have been asked by those who take a deep and special interest in the "Architectural Benevolent Institution," to remind the members of our Institute of its strong claims upon their aid and on their generosity, not only on our members, but on those of the whole profession. Though our numbers are now "legion," and may be counted by hundreds, instead of units, as in the good old days of monopoly, I find there are only 256 architects subscribing to this fund, and, out of that number, only 150 members of this Institute. This is not a satisfactory or creditable state of things, and contrasts very unfavourably with the action of the civil engineers in a similar work of sympathy. It is a subject which specially deserves the interest not only of this Institute, but of every architect throughout the land. We all know the vicissitudes of a professional life—the fluctuating nature of our practice—the struggles which attend an unsuccessful career, and even the misfortunes which sometimes await in mature age on those whose early prospects seemed so promising. There is probably no one in this room who cannot call to mind some instances of disappointed hopes, narrowed means, and even urgent necessity amongst members of our fraternity. And there are many instances we know nothing of—instances of men whose lives have been blameless, but unfortunate, and who are year by year reduced to that most distressing form of need—the need which craves but dares not beg relief. Although we number 519 Fellows and Associates, only 153 are subscribers to this professional society. Do not let this reproach exist any longer. The President, Mr. Sydney Smirke, has but lately made an earnest appeal in favour of that society, which is in urgent need of funds. Its working expenses are reduced to a minimum. Its annual receipts from subscriptions and investment amount only to £ 235., and last year £ 214. was disbursed in charity; and there is but a small balance in hand. It is not only architects themselves who seek its aid, but too frequently their widows and orphans, who need a helping hand. The dictates of ordinary benevolence, no less than the claims of professional brotherhood, ought to secure for this excellent and well-administered charity our support and co-operation. If we could secure another 100 or 150 subscribers, or if some would double their present subscriptions, the boon would be great. Gentlemen, this is not the place for a charity sermon, but I have a strong presentiment that I shall not have appealed to our profession in vain.

I find, on referring to the address which I had the honour of reading to you this time last year, that I indulged in certain Utopian dreams of union and fusion, and of a "single united and powerful body." They were at least innocent, and may have reminded some of you of the old saying that "*new* brooms sweep clean." Your broom has, however, gained age and experience since then, and is not so hopeful of realizing *all* he dreamt of; but I venture to think that a useful first step towards uniformity, at any rate, has been realized in the "Conference" we held last session. Crude and incomplete as may have been many of its arrangements, we have learnt experience, and we have at least called forth an interest amongst our professional brethren in the United Kingdom which, if well directed, and guided with patience and judgment by the administrative body of this Institute, will most assuredly bring forth good fruit ere long. Members will remember that it was decided last year to renew the "Conference" in June next, and that Special Committees were appointed to consider the important subjects of Professional Charges, Architectural Competitions, and the Employment of Surveyors. The existing committee of the Institute on "Professional Education," has been requested to continue its labours, so as to have that matter fully discussed and disposed of at the Congress in 1872. The three Special Committees have had appointed gentlemen to act as their secretaries, so as not to interfere with the general duties of Mr. Eastlake. From each of these gentlemen I have received notes, stating that one or more preliminary meetings have been held, and that a series of enquiries are being made; and that now, on the termination of what may be called the vacation, the committees will reassemble for work. I need hardly say how important it is that the members of the Institute should all co-operate; and should forward to the several secretaries (whose names have already been made known by a circular), any suggestions or facts, which their own experience may have called forth.

The country members who accepted our invitation, took much interest in this experiment, and seem to have been gratified at the result, as is evidenced by the cordial vote of thanks they passed to your Council for having brought them together. It must not be that our metropolitan body of architects are behind their provincial confrères in a work from which the latter anticipate "so much benefit to the profession."

The new "Metropolitan Building Act" does not seem to have made much progress during the last session. It was read a first time on the 10th May, and printed, but no further progress was made, and, if my recollection is correct, the Building Act promoted by the Liverpool authorities was thrown out in Parliament, some of its clauses having been considered unduly stringent and uncalled for, interfering very tyrannically with the rights of property.

It will, I feel sure, be gratifying to many present to hear that the school recently opened by the Royal Academy for the special study of architecture (and of which our member, Mr. Phené Spiers, is the master), is making steady progress; and, considering that it has been but recently established, Mr. Spiers is satisfied with the result. The annual number of architectural students admitted during the last ten years, has averaged eight or nine per annum; there is every probability that in December next, for the coming session, the number will be doubled. It seems most desirable that the course of study now instituded at the Royal Academy should be commenced in the earliest stage of a pupilage, by those who have entered it as probationers (a knowledge of design not being necessary for this purpose). Mr. Spiers would thus have a better chance of effecting good in the student's career, and of assimilating our system more nearly to that of the Beaux Arts in Paris. Mr. Spiers has lately been to Paris to study the operation of the system adopted at the "Beaux Arts," and at "l'Ecole Centrale" in that city, with a view to reporting to the Council of the Royal Academy on this important question. From the interest now taken by the members of that body on the subject of architecture, I cannot but anticipate satisfactory results.

I have amused myself this autumn with cutting out and collating the various letters and articles that have appeared in the public papers, on the subject of the "Law Courts," and a more painful bewildering array of criticism I cannot conceive, or one more likely to paralyse and destroy the powers and energy of the architect. Can there be a more painful instance of the disappointing way in which our great public competitions are conducted? of the unsatisfactory nature of the tribunal to which designs so submitted are to be subjected? or of the perplexing nature of the official control now exercised over our public buildings? I need not now dwell on the protracted and unexpected nature of the actual selection. Mr. Street had passed the ordeal of legal criticism, for if we may take a leading legal journal as our authority, "his plans and arrangements leave nothing to be desired." He had escaped "Scylla" in the person of that awful and much dreaded Œdile (Mr. Ayrton) only to be dragged into Charybdis, and engulfed by the Chancellor of the Exchequer (Mr. Lowe), and as though that fate was not enough to crush Mr. Street, he is now threatened with that most dangerous of all tribunals, "Parliament," a mixed jury of 658 members, of whom probably *six* may know something of the matter on which they are supposed to pass judgment! And then it is suggested that the "wheel of fortune" should have one more turn, and a new competition be originated, to go through the same protracted and useless routine! Gentlemen, if such a proposal should be decided on, which I can scarcely believe, I do trust that our profession will not have sunk so low, or be so lost to a sense of its own honour, as to permit any member of it to enter on such a competition.

I am well aware that this is said to be a land of liberty, where every one (qualified or not) enjoys the presumptive—not to say presumptuous—right to express his opinion on any given subject, and I can therefore understand that men like Sir Edward Cust, Mr. Denison, Mr. Cavendish Bentinck, and Mr. Alfred Seymour, who are supposed to have given consideration to the subject of architecture, and Mr. Sidney Smirke, who is known to have done so, should take an interest in the matter and express themselves freely, if not wisely. And I can even understand such professional criticism as Mr. Fergusson passed on Mr. Street's proposal to vault his great hall, and on his elevations, though I much deplored its tone and severity. I claim the right personally to criticise Mr. Street's design, and to express regret that the Strand front is so broken up into various and perhaps disjointed parts, so long only as I do so without personality or violence; but what can justify from one architect (in speaking of the works of others of his own profession) such a tirade of self-sufficient abuse as that contained in Mr. Welby Pugin's letter of the 9th September, in speaking of Mr. Currey, Mr. Scott and Mr. Street? Where is the "*esprit du corps*" of our profession when such flagrant violations of etiquette are tolerated? Amongst the various letters that have been published on this vexed question, I was much struck with this passage in one of them: "There are people "in the world who are so well satisfied with themselves, and so full of their own perfection, that "they are constantly endeavouring to bring everybody up to their own high standard, by offering "publicly their gratuitous criticisms, opinions and advice." Strong men are to be feared, "and the "wisdom of softening their anger is apparent." It may be so, but I trust that Mr. Street will not waste his valuable time on so useless and thankless an attempt.

Since I addressed you in November last, the Albert Hall has been completed and opened, and has no doubt added to the effect and usefulness of the International Exhibition. There seems to be a difference of opinion as to its acoustic qualities; but there can, I think, be none as to its internal effect being grand and impressive, and we certainly may congratulate ourselves on having one of the finest music halls in Europe.

In London Mr. Scott is bringing to a close his interesting restoration of the Chapter House at Westminster, and his monster Hotel at the St. Pancras Station; and the works under his charge for the Home and Colonial Offices in Downing Street are in full vigour.

The Post Office in St. Martin's-le-Grand has made great progress during the summer, and will assuredly add materially to the convenience of that department, if it does not to the embellishment of the city; but it would be unfair to pass any decided criticism upon its architectural treatment, until the building is completed and the scaffolding removed. This work has been the subject of parliamentary and literary criticism of a severe nature, and I will only express the hope that no professional jealousy will be allowed to interfere with a just estimate of its merit.

The works at Burlington House are again in full progress, after much loss of time, caused by the failure of the original contractors. Let us hope for an early completion of this group, for until the three sides now in progress are finished, the completion of the central or Royal Academy block cannot, I understand, be undertaken.

These, I think, are the principal public works now in hand in London, excluding from my list some very large and impressive churches, either just finished or in progress, such as the parish church of Kensington by Mr. Scott; the churches of St. Chad's and St. Colomba, at Haggerston, by Mr. Brooks; St. Jude's, South Kensington, by Messrs. G. and H. Godwin, and St. Augustine's, South Kensington, by Mr. Butterfield.

Bearing in mind that all these churches are erected by voluntary subscriptions, and that in several cases their cost is very large and their decoration abundant, surely no charge can be brought against the present generation, of illiberality or want of zeal in such matters! and these works in one city alone! whilst in many parts of the United Kingdom, works of similar importance and cost are in progress. (I know not where to get a correct list). In Ireland, where it might have been supposed that recent parliamentary legislation would have damped all church building ardour, we find Mr. Street entrusted with the restoration of that glorious old church, in Dublin, (Christ Church), to be done at the sole cost of Mr. Roe, jun. (a noble twin sister to the restoration of St. Patrick's, undertaken at the expence of Mr. Guinness). He has also been called in to report upon the ruined Cathedral of Kildare, with a view to its restoration. These are surely healthy signs.

I spoke last year of the works of restoration going on in our cathedrals, and I gave an abundant list. This year I shall only say, that there is no fallingo ff in the interest excited by these great works. Some are making good progress; others more leisurely, but not less surely; and fresh works of reparation have begun in others. But, gentlemen, I am happy to say that the liberality and energy of our countrymen do not exhaust themselves on cathedrals and churches: hospitals, infirmaries and asylums, all tending to relieve the sufferings of our fellow creatures, are being built by dozens (amongst which I may mention the new Royal Infirmary at Edinburgh, by Mr. Bryce, as probably the most important), and town halls and exchanges, and museums and galleries, are in progress in many of our large towns; all tending to bear witness to the wealth and energy and prosperity of our great country. Whilst we congratulate ourselves on such signs of prosperity and vitality, do not let us shut our eyes, or close our hearts, to the misfortunes and sufferings of other countries, in matters specially interesting to us as architects.

I spoke last year of the bitter struggle that was then at its height between France and Germany. We could but deplore it, and hope for a speedy termination to such misery: but we could not foretell the sad grief that has fallen on Paris as a city: we could not foresee that her own sons and daughters would raise their hands against her glorious buildings, which had been respected and spared by her enemies: or imagine that French men, and French women, would be so lost to every feeling of pride and civilization, as to destroy wilfully, and in cold blood, monuments that were the glory of their fathers and the envy of their neighbours! But we may have much faith in the energy and elasticity of Frenchmen, if not in their judgment and dignity; and ere long we shall undoubtedly see the restoration of

these fine monuments. The façade of the Tuileries is not, I hear, to be retained or restored in its whole length, but the present centre, or clock tower, is to be connected with the two end pavilions, "by "removing the intermediate ruins, and by substituting for them a mere curtain, either a colonnade or a "series of open arches like those of the new Louvre." As a mere "coup-d'œil," and irrespective of any question of history or archæology, I believe the gain will be great. Gentlemen, we have sought to aid materially this nation, once our bitter foe, and latterly our friend and ally, in her moments of suffering and depression; let us now wish her "God speed" in her day of revival.

Nor is it France alone that should call forth our aid and sympathy! That great nation across the Atlantic, to which we are closely allied by ties of blood and language—a nation

"Who speak the tongue that Shakespeare spoke,
"The faith and morals hold which Milton held,"

but just recovering from that desolating, bitter civil war, which would have annihilated any other nation with less energy and endurance—has, in her great western territory, undergone such a visitation from fire as hardly ever before fell upon a people! It has witnessed not only the almost complete destruction of that wonderful city Chicago, and the suffering and loss of life that must have ensued, but such a series of inland fires, destroying whole districts and settlements, and life and property, as can hardly be imagined. It is true that to the world of art the losses bear no comparison with those of France, but it must be a bitter grief to the inhabitants of Chicago, to see their great public buildings, which they had so recently raised with pride and hope, "giving of their best," in money and in skill, swept away like tinder. There is, however, a vitality and resolution, so strangely bound up in the American character, that we shall assuredly see, in an incredibly short space of time, this city rebuilt, and the public buildings replaced, even on a grander and more perfect type; for I believe there are architects in America who are quite capable of turning to good account this sad opportunity of proving the progress that has been made of late in their profession.

It is a pleasure to think that the appeal which has thus been made to the sympathy and aid of Englishmen, has been heartily met; and our response cannot, I believe, fail to remove prejudice, and to draw closer together two great nations, whose common origin and mutual interests should render mistrust or war impossible.

It may not be uninteresting if we now turn for a moment from the vanquished and the suffering to the triumphant and the prosperous—to Germany, and see what progress our profession is making in that country, and what important works she has in hand. Knowing that my brother (Sir Digby Wyatt), was about to have a holiday and make a tour in Germany and in Austria, and having confidence in his quick observant eye, I requested him to make some memoranda of the important public architectural works in progress which he might see, so that I might have them to lay before you on this occasion, knowing that they could not fail to interest the members. He has kindly done so, and I think you will agree with me, that they give a very hopeful and valuable account of the progress of architecture in those countries. He tells me that during the past year the anxieties and expenses connected with a state of war have almost entirely checked the undertaking of new works at Berlin; but it has seen the completion in that city of some structures of considerable interest, particularly in the technicalities of building. The new "Rath-haus," or Town Hall, is a structure upon which vast sums have been lavished, and an effort has evidently been made to rival the magnificence of the now destroyed Hotel de Ville at Paris. The general effect is not commensurate with the expenditure; but the beauty of the oak carving, of the terra cotta, of the ironwork, and of the ornamental floors generally, reflects the highest credit upon the present condition of the building

trade in Prussia. What is perhaps most to be admired in the Town Hall at Berlin is the magnificence of the carved wainscot ceiling in the hall, where the magistrates hold their meetings. What is most to be regretted is the sombreness of many parts of the interior, and the vulgarity of the stained glass, which adds to the gloom. Although not so ambitious, the new Finance Ministry building is much more satisfactory. Its façade, which recalls some of the Pisan and Florentine buildings of the end of the fifteenth century, displays a great propriety of parts and much elegant detail. The new Mint, which is an immense structure, somewhat resembles the Ministry of Finance in its style, but is less congruous in bringing together its leading features. Much regularity and almost severity of general style is marred by eccentricities here and there tending almost to caricature. There are certain great consoles with figures of miners executed in a quasi romantic style, which quite distract the attention of the observer from all the adjoining architectural detail. They are neither strictly ornamental or functional, and they furnish an illustration of the bad effect of that struggle to retain a sort of Mediæval comicality, which not unfrequently disfigures otherwise clever designs in our own country. These buildings are all of brick and terra cotta, and manifest that there is no deterioration in Berlin in the use of such materials since Schinkel designed his original and admirable " Bau Akademie."

At Vienna the value of a year of peace shows itself in the completion of many architectural works of the highest merit. A more noble boulevard than that constructed upon the old line of city defences cannot be imagined. The magnificent " Franz Joseph " Caserne, with its great exercising ground and its town gate opposite to its central mass, is certainly the most skilfully designed barrack in the world: simple in its parts, these parts are so brought together and contrasted as to form a grand and effective composition, and it shows, in the hand of a truly accomplished architect, how much grandeur may be obtained in structures of the most utilitarian kind. The new Opera House is certainly about the handsomest Renaissance building in Europe, and is no less admirable in its external effect than well suited in every particular for its purpose. The " Votive Church," as a Gothic structure, is very elaborate, and beautifully executed. There is, however, a certain " cast-irony " hardness in its details: it is too florid, and illustrates the bad effects which the over admiration the Germans have bestowed upon the open-work spires of Cologne Cathedral, have occasionally led to in that country. As a general feature of the noble new street architecture of Vienna, there may be remarked the frequent use of external gilding and polychromy, sometimes obtained by actual painting, and more frequently by the contrast of variously coloured terra cottas and other materials. Many of these structures reflect the highest credit upon our Honorary and Corresponding Members Ferstel, Schmidt, and Hasenauer, all of Vienna. At Dresden the foundations for the magnificent structure which our Honorary Contributing Fellow Professor Semper has designed to replace his chef-d'œuvre, which was, it may be remembered, destroyed by fire, are making slow but steady progress.

At Brussels the great works commenced by the " Belgian Improvements Company " are beginning to show themselves. It is singular, however, that in this thriving city there does not appear to be manifest the same anxiety on the part of the public to occupy the vacant land in good positions which is shewn at Vienna; and it is also to be regretted that the tendency shewn by many of the great buildings now in progress, or recently completed in this city, is towards heaviness of form and redundancy of ornament, rather than to that purity and severity of style which characterized in so high a degree the great work of our Honorary Member M. Duc, at Paris, the Palais de Justice, which even in its ruin resembles a magnificent fragment of the best days of Imperial Rome.

There are few towns upon the continent which show more conspicuously than Leipsic the value of the association of art with wealth in the improvement of a city. There the combination of architecture with landscape gardening is most successful; and the placing of the fine theatre in connexion with its

elegant cafés and other buildings, looking over a piece of ornamental water with vistas, judiciously planted, produces an effect of novelty no less than beauty. The villas of the rich merchants are not only comfortable, but frequently beautiful; and it is a happy circumstance to recognize the skill with which the architects abroad succeed in this combination. To some extent, no doubt, this result is obtained by the establishment of museums, in which the luxurious wants of the rich citizens of former ages were supplied by cotemporary art workmen. In almost every town on the continent such museums are now accessible to architects, art students and workmen; and although we must rejoice in the extended developement of institutions such as the South Kensington Museum, the Crystal Palace, the Architectural Museum, the Meyer Institution at Liverpool, and some others in this country, it is to be regretted that there are still many large centres of industry and of population, such as Birmingham, Leeds, Sheffield, &c., very inadequately supplied with such opportunities for study.

Such, Gentlemen, is the budget of "Home and Foreign news" which I have thought it my duty to lay before you.

The President then read the following

LETTER FROM PROFESSOR DONALDSON.

"*Rome, 30th October*, 1871.

"Dear Mr. President,

"I have just received your letter of the 25th with much pleasure, and can only acknowledge it by a few words. The Government have allotted to Signor Rosa, architect, 12,000 lire Italiane annually to go on with excavations, which he is pursuing judiciously and vigorously. He is cutting a wide trench from the Column of Phocas in the Roman Forum, up to the Arch of Trajan, and laying bare the base of the building (now represented by the three columns, called of old Jupiter Stator), and now supposed to be a mere vestibule to the Senate House, in fact the scanty width which the excavations disclose take away the character of a temple. It is curious that very few marble fragments have been found in the accumulation of soil there. It is mortifying to think that those three exquisite columns should belong to anything of less importance than an Augustan Temple of the first class. It is said that in clearing away the accumulations of soil from the Thermœ of Caracalla, he has gone down to the very floor of the several halls, but I have not yet had time to visit his operations there. He, Monsieur Rosa, is a man *that we must have at our Institute*, and I presume that the plan of the Capitoline Hill which he has laid bare, and the masses of which he has attributed to certain buildings and sites mentioned by ancient authors, will, in the eyes of the Council and Members, entitle him to the position of Hon. and Corresponding Member. Besides, it is very useful for our members who come here to be able to claim the privilege of a fraternity with him. There is also a certain Cavaliere Cipolla, Government Architect, of whose works I have received photographs for the Institute, well worthy to be one of our Correspondents. I have to-day been to the Chambers of the Senate and Deputies, the one in the Palazzo Madama, the other in the old police office of the Monte Citorio; both of these able temporary buildings, and evincing considerable ingenuity in the architects, the Signors Gabet and Commotto, the latter established at Genoa, who might, perhaps, fill up the vacancy caused by the death of Signor Gardella, of whom I know nothing except that at the time he was strongly recommended by Mr. Smith? who was at Genoa for some time, and I think his letter of recommendation will be found annexed to the paper of Gandella's election. Notre Dame de la Garde is *not* by Leon Vaudoyer; but by his pupil, according to Coste's own words. Vaudoyer's work is the great Cathedral at Marseilles, near the harbour and docks, and for the

present at a standstill for the want of funds. Boulnois, our member, is now here with his wife. I am distressed to hear the danger in which F. P. Cockerell has been. His life is a valuable one for our art, and I trust he will now, in God's providence, soon recover.

"I have been making enquiries as to rents and purchases of plots of land in Rome. The price seems almost, if not quite, as high as in London. The owners are mad, and take advantage of the present demand to ask fabulous sums. Imagine £600. for the first floor in the Corso for six months! They say our ambassador is frightened, and intends to have a mere office here and his residence in Florence. But in two or three years, when the Senate and Parliament have confirmed the suppression of the religious establishments, and other vast possessions in and out of Rome, then there may be a glut in the matter and prices will assume their just level."

MR. EDWARD HALL, Visitor.—May I be allowed to add one word to the excellent address we have just heard, by mentioning the name of Mr. James W. Fraser, whose decease I regret to state occurred about two months ago. Mr. Fraser I knew as far back as 1836, at which time he was the most eminent amateur architect in the town of Manchester, a most able artist, an exhibitor at the local exhibition of the Royal Institution in Manchester, and had a great taste for architecture. I remember about that time his frequent attendances at the offices of my master, Mr. Atkinson, of Manchester. He came there on any emergency when drawings were required to be filled in with figures; he was peculiarly apt at such work. He went to London, where he afterwards resided, and it is probable some members know more about his recent history than I do myself; but I think his name ought to be mentioned as one of the prominent members of this Institute.

THE PRESIDENT.—Mr. Fraser was a Contributing Visitor. Up to the present time we had received no intimation of his decease, which I am sure all of us now hear with deep regret. It will of course be formally recorded in our Minutes.

PROFESSOR KERR.—Every one present will, I am sure, have remarked that the address to which we have listened with so much pleasure, is one of a peculiarly practical and useful character, and commends itself to every one who understands anything of the subjects treated of. We can at this time of day dispense with high-flown orations, and may rest upon that more simple but more useful basis of a plain statement of facts, which our President is always good enough to give us whenever he addresses us from that chair. It has occurred to me that the President's remarks are very just upon the condition of what may be called the educational question in our profession at this moment. Certainly all of us who are getting into middle life, and a little past it, must draw a distinction between our opportunities, such as they were, and the opportunities of our successors, such as they are: and we must agree with the President that those opportunities ought to be embraced by the younger members of the profession with greater ardour than they have been. We must also agree that the Architectural Examinations held here, at a most liberal expense on the part of the Institute, have not generally, and more particularly last year, received that attention from young men which we were entitled to expect. At the same time I am bound to say that there were some good excuses for the failure of last year; though I for one have ceased to attach importance to excuses of any kind. What the excuse was I do not call to mind: I hope it will not be offered again. I hope on the next occasion of the examinations we shall have a good supply of candidates, and I trust the examinations of the past afford a sufficient guarantee that we are inclined to deal with those who come forward with the same discrimination and at the same time consideration which have always been exercised. The accounts which the President has given of the condition of architecture in England and on the continent it is unnecessary for me to follow, but it is one which is eminently instructive, and is replete with information which could hardly have been

obtained from other sources. The President was modest enough to say that the principal part of his discourse had been supplied to him by others. We scarcely think so. We have listened to the admirable letters of our good, old, dear friend Professor Donaldson. I hope we shall soon see him amongst us again, as good-tempered as he always has been. He has sent us one of those peculiar letters, full of information, and full of that inexpressible energy by which he has always been characterised, and which I hope he may live long to display in untiring vigour. Our distinguished friend Sir Digby Wyatt has also given valuable particulars, which the President has been good enough to read to us. I am sure he will not consider the association of those gentlemen in the acknowledgments we wish to express an unworthy one; but he is none the less on that account entitled to our thanks for having worked in those interesting particulars so effectively in their proper places and in their proper position in his discourse. I have now only to ask the meeting to join in awarding to the President a cordial vote of thanks for the excellent discourse he has delivered to-night, with the hope that during the session so well inaugurated we shall prosper as much under his further presidency as we have in the past years.

MR. G. AITCHISON, Fellow, seconded the motion, which was passed by acclamation.

THE PRESIDENT.—I have very little to add beyond the expression of my thanks for the great kindness you have shown, and the great patience with which you have listened to me whenever I have had occasion to trespass upon your attention. I have never aimed at eloquence, nor have I attempted to deal with questions of artistic interest, because they have been amply discussed by my predecessors, who were well qualified for the task, and are fully dealt with in our Papers at the Ordinary Meetings of the Session. I have confined myself to practical questions affecting our profession, which I feel to be more within my powers. As they have presented themselves to my mind so I have offered them to you, and I trust they may not be altogether unproductive of good. My pride will be to leave this chair with the recollection of your approval, and with the hope that such duties as I have been enabled to discharge as your President may not have been without some service to the Institute.

The Meeting then adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 20th November, 1871, the following Paper was read, THOMAS H. WYATT, President, in the Chair:—

THE REVIVAL OF GOTHIC ARCHITECTURE IN GERMANY AND HOLLAND.

By H. W. BREWER, Esq.

GENTLEMEN,—The great difficulty which exists of thoroughly understanding the modern architecture of foreign countries, arises from the fact that it is next to impossible for any stranger to become well acquainted with the various causes which have influenced the building arts of those lands. So, in speaking of the two schools of ecclesiastical architecture at present practising in Germany, I shall endeavour, as much as possible, to criticise them from their own stand point, and not from an English point of view. I shall try to ascertain, as well as I can, what they are aiming at, and where they have succeeded in attaining the end they were striving after, and where they have failed. At the same time I shall bear in mind the fact that there are certain fixed laws which must never be broken, however styles may change or tastes vary. Now I think every one will agree with me that the first of these immutable laws is, that an architect must be well acquainted with the style in which he is working. If, for instance, he is building in one of the mediæval styles, he must know pretty well what our ancestors would have done had they had the same wants and requirements to work for that he has, in other words, he must thoroughly understand the spirit of the style which he has taken up; and if an architect is building in a new or eclectic style, he must be thoroughly acquainted with all the elements out of which he is going to compose this style, and those elements will, of course, be the architecture of former times and different countries. Of the two styles of ecclesiastical architecture at present in use in Germany, I shall speak first of the eclectic or Munich style, because, by a singular contradiction, the Gothic or mediæval school is more recent than the eclectic school; had the reverse been the case, perhaps the result might have been more happy than it is at present. Now, after making every allowance for difference of taste, and for circumstances which may have influenced it, I find it impossible to say a single word in favour of the Munich Eclectic style—the "Architecture for the Future" as they have pompously named it. I say that it is not an architecture for the future; and simply for this reason, in the first place, it isnotarchitecture at all, and in the second place, men who cannot compose an architecture for the present certainly cannot invent one for the future. Now, let us for a moment see what this so-called eclectic style is. Well, it is a chaotic jumble of Romanesque, third-pointed Gothic, Italian, pure Greek, Indian, Chinese, Moorish and Venetian Gothic, all heaped together without the slightest considerations of necessity or propriety! Take for example the new "Maximillianum" and the "Maximillian Strasse" at Munich, or the Ludwig's Kirche, and any other building in the same style, of which unfortunately there are thousands, and what do we see—badly designed Romanesque windows, utterly devoid of spirit and feeling, filled in with badly designed and graceless third-pointed tracery; badly designed Moorish parapets; badly designed Venetian Gothic crockets, budding from meaningless sham gables; the general composition presenting no more variety than a series of uninteresting parallelograms, covered with nearly flat roofs composed of ungainly tiles, and the building faced with glazed carrot-coloured brick. It is all very

well to call this conglomeration of discordant elements a new and original style, but novelty may be of two kinds—a thing may be new, either because no one *could* have done it before, or because no one *would* have done so before. However, the worst feature of this style is not its artistic part, though that is bad enough, but its faulty construction. I have frequently seen the jambs of a doorway or window, 10 or 12 feet high, all worked out of one piece of stone only about 10 or 12 inches square, and this stone *beam* is set on end and made to support a Gothic arch, the sides of which will again be composed each of a single stone, with a huge key stone in the centre.

Then again imagine the absurdity of nearly flat tile roofs in a country like Bavaria, where the snow is often 4 feet deep, and lies for nine or ten days. I am sorry to say that this style has carried everything before it in Germany—invented in Munich (and unfortunately not patented)—it has been introduced into Berlin where it has perpetrated dire eccentricities. To Stuttgard, Hanover, Dresden and Carlsruhe, in all which places it has become a great court favourite, and has been warmly taken up and pushed by the various *Ayrtons* attached to those governments. Yes, Gentlemen, you are not the only architects in Europe who suffer from *Ayrtonism,* for, believe me, you can form no conception of the extent to which Ayrtonian principles have developed in Germany, especially in Berlin. In fact the interference of the German governments, particularly those of Prussia and Bavaria, has had a disastrous effect upon architecture in those countries. I will give you an example of this: When Zwirner died, the inhabitants of Cologne, the "Dom-bau Verein," and the archbishop, all wished Herr Stadtz, of Cologne, to be appointed architect to the cathedral. Now Herr Stadtz is a Cologne man, and knew every stone of the cathedral; he had, in fact, worked upon the building as a mason, in order to become better acquainted with his profession and to have a perfect knowledge of that splendid church. Herr Stadtz had also greatly distinguished himself by numerous fine churches which he had erected in the archdiocese. But, despite all remonstrances and advice, the great Prussian *Ayrton* forced upon the clergy and people of Cologne an architect, who, of course, was a Berliner, and whose knowledge and feeling for Gothic architecture may be judged by the insignificant little terrace with its petty little pierced parapet and its puny buttresses, which he has placed as a basement to this noble building.

I will now leave the Munich Eclectic style for the present, and speak about the Mediæval School of Architects. The first really good Gothic church built in Germany was the work of an Englishman. I refer to Mr. G. G. Scott's beautiful church at Hamburgh. Before the commencement of that building the Eclectic School and the Italian School of Ecclesiastical Art divided the field between them. Mr. Scott's church, however, was the commencement of a great reformation in ecclesiastical architecture; the Italian school died out at once, and a new school of Gothic architecture arose. There is, however, one fact that must be noticed, and it is this—that although the Lutherans made the first move towards the re-introduction of Gothic architecture, by the selection of Mr. Scott's plans for St. Nicholas, Hamburgh, they appear to have reaped little, if any, profit from that movement, whereas the Roman Catholics, who were later in the field, have taken great advantage of the good example set them in ecclesiastical architecture by Mr. Scott. As a rule, the new Protestant churches in Germany are built in the eclectic style, and the new Catholic churches in one or other of the mediæval styles. There are of course a few exceptions to this rule, for instance, the new Protestant church at Bonn is in a kind of Gothic style, and the new Catholic church at Wiesbaden is in the "Munich-Eclectic" style. With regard to the churches built by the "Architects for the Future," the first thing that strikes one is their extraordinary similarity—one would imagine that there must be a stereotyped pattern kept at Munich from which they are all cast. The only difference observable amongst them is that some of them have, and some are without pinnacles. They nearly all consist of one broad nave, covered with sprawling tile roof, an apology for a chancel, in the shape of a little apse stuck on at the east end (of course it

is just as often the west end, as orientation is not observed,) and a thin tower and spire over a porch at the opposite end. This tower is nearly always gabled on each face, and has a round-headed window and a rose window on each side; sometimes the rose window is above the long window, and sometimes the long window is above the rose window. Iron is largely used for the window tracery and the roofs; and, in fact, wherever it can be used with impropriety and bad effect. Examples of this style of building are the Lutheran churches at Freising, Aschaffenburg, St. Goarhausen, Bingen, Ems, Limburg, Deetz, Landshut, Ludwigshafen, Mühlheim, Mainz, Donauworth, &c. &c. The new Lutheran church at Wiesbaden is one of the largest examples of a church in this style; and its size and solidity redeem it from the usual vulgarity of these buildings. When I say that Mr. Scott's church at Hamburgh commenced a new era in ecclesiastical architecture in Germany, I don't mean to say that it was by any means the first Gothic church built in Germany during the Revival, for two rather interesting examples had preceded it — the churches at Apollonarisburg by Zwirner, and at Au, a suburb at Munich, by Oemüller. The former, however, although the detail is pretty, and its decoration sumptuous and splendid in the extreme, is merely a costly toy; and the latter, although one of the most expensive churches ever built, is far from being a satisfactory building. Like every thing in Munich, it is simply a "specimen," and as such, of course, would never exercise the slightest influence upon the art of the country at large.

If you wish to find the school of real German Gothic architects, you must not look for them in the capitals of the various German States. You search for them in vain at Berlin, Munich, Dresden, and Stuttgard; but you will find them in the provincial towns. At Cologne, Aix-la-Chapelle, Paderborn, Hildesheim, Brunswick, Fulda, and Ratisbon, where they have learnt their art in the study of the noble minsters and parish churches of their native towns; snubbed by the courts and governments, laughed at by their more successful rivals the "men of the future," as so many antiquaries, and as being five hundred years behind the age in which they live, completely shut out from government work in a country where nearly every great undertaking is in the hands of the government, they have had to seek for patronage from the town-councils and clergy of their immediate neighbourhood.

Amongst the architects of this school, whose works seem to me to approach nearest in spirit to those of the great Mediæval builders, I will mention the names of Herr Stadtz, of Cologne; Herr Guldenpfennig, of Paderborn; Herr Denzil, of Fulda; Herr Denzinger, of Ratisbon. There are also two other gentlemen, whose names have unfortunately escaped my memory, whose works are to be seen at Hildesheim and Brunswick; nor must I omit to mention Herr Kleinertz, of Cologne, whose superb decoration of St. Maria in Capitolio at Cologne, and other churches in that city, and in St. Catharine's at Utrecht, are works of the very highest excellence in decorative art. Dr. Bock, of Aix-la-Chapelle, and Dr. Reichensperger, of Cologne, deserve also to be mentioned for their many admirable works upon Gothic architecture and church furniture; and Herr Baudri, of Cologne, for his attempt to restore stained glass to its proper use and character in opposition to the gaudy and vulgar transparencies of the Munich School.

One of the chief works of Herr Michel Stadtz, of Cologne, is the new cathedral at Lintz on the Danube, an immense church 410 feet long and 205 across the transepts. The nave has single aisles, and the choir, which is of great length, terminates to the East in an apse and chêvet, with radiating chapels; at the West end is an immense tower and spire, 50 feet in diameter, flanked by a baptistery and a mortuary chapel; the style of the whole is middle pointed, and the whole church vaulted is in brick with stone ribs. The work of building this immense church has been going on for some twelve years, and is still far from completed.

St. Mauritius, at Cologne, is another very large and striking church, about 220 feet long, and

about 160 across the transepts. It consists of a nave and aisles of seven bays; apsidal transepts; a choir of three bays, terminating in an apse, pierced with two tiers of windows, and four apsidal chapels, filling up the spaces between the choir and transepts. At the West end is a lofty stone spire, which is the poorest portion of the whole design, and anything but satisfactory in outline. Internally the whole church is vaulted in stone, and the main arches, triforium and window jambs are all richly moulded, and of the same material. This church is quite finished, and the windows are being filled with stained glass, which, though wanting in richness, is a wholesome protest against the Munich school. The altars are very simple, consisting merely of stone slabs, supported upon columns with carved capitals. The defects of this church are, firstly, the disagreeable outline of the tower and spire; secondly, the introduction of a badly-designed doorway into the apse of the North transept; and thirdly, the construction of the doorways themselves, for here the architect has adopted the Munich plan of making the whole jamb out of one piece of stone; there are also keystones to the windows; but, as they are kept very small, they cease to be objectionable.

Herr Stadtz's church at Aix-la-Chapelle is similar in general arrangement to that at Cologne, except that here there is no western tower; instead of which, there is an open lantern over the crux, and the transepts are square ended instead of apsidal. The western front is the least successful portion of the whole design, and has a busy and fussy appearance; the arrangement of the gable too is far from happy. The interior of the church, however, is very striking; and the high altar, with its metal reredos and shrine, is a good example of modern church furniture. The side altars have pointed triptych reredoses of simple design, but still effective.

The church at Muhlhausen is an equally large cruciform church, but is much plainer than the two former ones. It is not vaulted, but has a very simple king-post roof. The effect of the interior at present is rather bald. The spire, which is of slate, is far preferable in outline to that of Herr Stadtz's Cologne church.

The churches at Kaevlaer and Eupen are also large and important churches, but my time will not allow of my describing them, or the very numerous other ecclesiastical works of this talented architect. I must however mention this new building called the "Karlshaus," at Aix-la-Chapelle, as a good example of German Domestic Gothic; like all Herr Stadtz's work, is early second pointed.

The works of Herr Guldenpfennig, of Paderborn, are, certainly, the most satisfactory examples of modern German Gothic that I have seen; and as he is a young man, I think great things may be expected from him. I am glad to say that he has been appointed Diocesan Architect to the Bishop of Paderborn, in which capacity he is restoring the fine cathedral of that town in a most skilful and excellent manner; in fact, I have no hesitation in saying that it will, when completed, be the most thoroughly satisfactory restoration in all Germany. I mention this restoration especially because it does not simply consist of restoring what was decayed, or defaced, but of replacing features which had been entirely destroyed for many years. I should explain that the cathedral of Paderborn is a noble church, 360 feet long by about 200 across the transepts, and that the nave and aisles are of the same height, with every bay gabled laterally. Now, not only every one of these gables, but also the gables of the transepts, and the eastern gable (it is a square-ended church), had been destroyed or modernized about a century ago. Herr Guldenpfennig has rebuilt all these gables in the same style as the cathedral; that is to say, the style of the earlier part of the 13th century. They are, every one of them, different in design, and are singularly original and beautiful. The restoration of the interior of this fine church is only just being commenced. A new school, a college, and several dwelling houses in Paderborn, by the same architect, are all excellent; one of these houses was so picturesque and spirited that I could hardly have believed it to be the work of a modern German architect. It stands on the old ramparts

of the town, and is only one of a number of houses being built there by the same architect. All these houses are thoroughly local in character, which adds greatly, in my mind, to their interest. Herr Guldenpfennig has erected two very remarkable churches in the neighbourhood of Paderborn. The first is at a place called Hoerde and the second at Buderich; both are cruciform in plan, and of large dimensions. The church at Hoerde consists of a nave of six bays, aisles, centre tower and spire, transepts and chancel. The whole is built of brick, with stone used alone for the window tracery and strings, but internally stone is more freely used, as the columns, arches, vaulting-ribs, &c., are all of that material. The church at Buderich is a rather more elaborate building. It consists of a nave and aisles of four bays, transepts, and an apsidal choir. There is a large western tower and spire, flanked by short turrets (a regular Westphalian treatment). Internally the whole church is vaulted, the columns are very solid, and the walls very thick, and the whole building has a solemn and dignified appearance very unlike the work of most German architects. A very pretty little domestic chapel built at Wever for the Baron von Brenken, and a grange for the same nobleman, are deserving of notice. The designs for a new church, entirely of brick, at Laer, near Dortmund, show considerable originality and knowledge of the material to be used. The beautiful Lieb-Frauen church at Munster is being restored by the same able hand; at present, unfortunately, this restoration has not progressed very far, but two new altars which I saw there are wonderfully good. Herr Guldenpfennig does not appear to have done very much work yet, but what he has done is so excellent, so far above anything else that I have seen in Germany, that I cannot help expressing a hope that The Royal Institute of British Architects will keep an eye upon him, as I feel sure he is destined to do great things.

Herr Denzinger, of Ratisbon, is best known by his design for the completion of the exquisite cathedral church of that city. This design bids fair to be carried out; in fact, the two lofty western spires, which form the most important portion of it, are already completed; they are graceful examples of openwork spires, and harmonize well with the magnificent façade to which they form so appropriate a termination. It is to be hoped that the open lantern over the crux of the cathedral will also soon be constructed. I cannot tell how far Herr Denzinger has been influenced by ancient designs or drawings, but it seems to me that the way in which this octagonal lantern is set on its square base is capable of improvement.

Of the works of Herr Denzel, of Fulda, I know only one. The restoration of the Benedictine church in that town, however, there is much that is excellent in this restoration, and there is a greater knowledge of Gothic architecture shown in it than in most German restorations.

I have not yet spoken of the Ecclesiastical Architects of Austria, and it is scarcely within my province to do so; however, before concluding the few notices I have given of German architects, I should wish to mention the names of Professor Schmidt and H. Ferstel, both of whom have taken an active part in the revival of Gothic architecture in that country. The votive church at Vienna by Ferstel was certainly the first Gothic church worthy of the name commenced in the Austrian dominions; and the Lazarist church at Vienna, by Professor Schmidt, is certainly a very satisfactory Gothic church. I cannot help thinking, however, that his churches at Weissgraben and at Fischerhoff, near Vienna, are less admirable, although the latter is certainly a clever and a not unsuccessful attempt to design a Gothic church with a dome. His design for the new Town Hall at Vienna is in a mixed style of Gothic and Italian; that, I venture to think, is not an advance in the right direction, although it is vastly superior to anything of the kind that has been done at Munich. Of course there are several other architects in Germany who have done good things, and whose names, either from a want of knowledge of their works, or from want of space, I have been obliged to omit. But as

a rule the German architects, with the exception of those I have named, seem like men speaking in strange language, when they attempt to build in the Gothic style.

I must now leave Germany, and say a few words about the Dutch Revival. Twenty years ago there was no such thing as ecclesiastical architecture in Holland of any description whatever; both the Protestant and Roman Catholic churches consisted of four walls, with a pepper-box at one end, and an altar or reading desk at the other.

In order that you may the more fully understand how the revival was brought about it is necessary that I should say a few words about the different religious bodies in Holland. By the last census taken 1865, religious parties in Holland were divided as follows: Protestants of the Geneva Confession 1,942,387, Roman Catholics 1,234,486, Remonstrants about 100,000, Lutherans about 50,000, Jews 150,000, and about 8000 Jansenists, or Members of the Church of Utrecht. The clergy of the Dutch Church and the Roman Catholic Church are both allowed an income by the State, and a very small sum is granted yearly to keep the churches in tolerable repair, that is, to keep them from falling down. Now about twenty years ago a revival of Gothic architecture commenced amongst the Dutch Roman Catholics, which for enthusiasm, boldness and liberality has certainly had no equal in Europe. Whether we regard the great number of churches, their completeness or the important dimensions of many of them, it seems marvellous that they could have been erected by a people numbering little more than one million. Nor has the movement been confined to building new churches only, for nearly all the ancient churches and cathedrals that have remained in the hands of the Roman Catholics have been or are undergoing a thorough restoration. The cathedrals of Maestricht and Roermond are being excellently restored by M. Cuypers. St. Catherine's at Utrecht, originally the Carmelite Church, but now the Roman Catholic Cathedral of that city, has undergone a thorough restoration by Herr Van der Brinck, and has been most beautifully decorated by Herr Kleinerts of Cologne, and fitted up with a fine set of carved oak stalls, sedelia, bishop's throne, altars and pulpit by Engleberger of Aix-la-Chapelle. The cathedral of Bois-le-Duc, the most magnificent building in Holland, is also undergoing a thorough restoration. This superb church has been not inaptly called the Dutch Cologne, and it bears a remarkable resemblance to its great German prototype. During the last century, however, every window in the church was deprived of its tracery; this is being carefully and well restored. The yellow wash with which the interior of this noble building is bedaubed is also being removed; and I wish this was all I was obliged to say about this well-intentioned but not altogether judicious restoration, for I think every lover of art, however Gothic may be his sympathies, must regret the removal of the fine renaissance rood screen. And the new high altar and bishop's throne are too small and insignificant for this fine cathedral. Then, again, the restoration of the sculpture in the great north front is careless and incorrect. The architects are MM. Hesseman and Vennemans of Bois-le-Duc. The ancient churches of Venloo, Boxtel, Sittard, Rolduc and St. Walburg at Arnheim are being admirably restored by M. Cuypers; and lastly, the beautiful Church of our Lady at Roermond, the finest example of late Romanesque and transitional styles in Holland, is being thoroughly restored and completed by the same architect. The restoration includes the building of the four towers and spires, which were only carried as high as the roof, or had been destroyed. I should mention that there has been great controversy about the dome of this church. Many persons consider that M. Cuypers ought not to have retained it in his restoration; he, however, maintains that the dome is at least as old as the commencement of the 16th century, and in all probability was then only a restoration of an earlier one of similar form. I should mention that all the designs for the restoration of this church have received the approbation of M. Viollet-Le-Duc. With regard to the works of restoration carried out in the churches belonging to the Dutch Calvinists little need be said. The church at the Hague has had a cast iron spire and pinnacles

added to its tower, and the whole of its exterior has been neatly plastered! The Grand Cathedral at Utrecht has had two new galleries in the form of the boxes of a theatre erected in its superb transepts, while its forlorn but graceful choir is still unoccupied. A pretty little doorway, which led into the cloisters, has been "repaired," that is, the sculpture has been removed from its tympanum, and its place filled in by a representation in stone of a neatly bound Bible, surrounded by rays. Some Gothic windows of a highly original and purely 19th century pattern have been inserted in the sacristies. The great church at Gouda is having its west front neatly restored in stucco. The great church at Rotterdam has been embellished by the addition of plaster quoins. The noble tower of the great church at Breda is being patched up, but the fine lantern over the crossing was destroyed some ten years ago. The beautiful monument of John of Nassau in this church has fortunately been restored by M. Cuypers, but the church itself is in a condition that is simply disgraceful; the nave alone is used, and the transepts and choir are allowed to go to ruin their own way. When I was there I saw a clothes line suspended across the transepts, upon which was displayed the week's washing of the pastor and his family. I remember to have seen the same remarkable display of ecclesiastical vestments in a similar position at Bergen-op-Zoom.

The first really successful new church erected in Holland was M. Cuypers' church at Wyck, near Mastricht. It was only commenced some fifteen years ago. It is a fine simple cruciform church, consisting of a nave and aisles, transepts and a deep chancel terminating in a three-sided apse. There is a lofty tower and spire at the west end. The entire length of the building is 163 feet, width across the transepts 91 feet, height of nave 62 feet to the vaulting, which is of brick, with stone ribs, height of spire 221 feet. The whole church has been recently well decorated. The altars, stalls and other furniture are remarkably good. The same, however, cannot be said for the stained glass, which is not satisfactory.

Of M. Cuypers' churches the most remarkable for completeness and decoration are those of Vechel and Eindhoven.

The church at Vechel consists of a nave and aisles of six bays, transepts, a deep choir terminating in a chevet, with five radiating chapels, two of which are triangular in plan, the other being all apsidal. The whole church is vaulted in brick, with stone ribs; brick is also the material used for the walling, the columns are of grey granite. The style chosen is 13th century, and the dimensions are as follows: entire length 245 feet: width of nave and aisles internally 72 feet: nave in the clear 32 feet: height to vaulting 72 feet: height of tower and spire 268 feet. The church contains eight altars, besides a baptistery and mortuary chapel; the vaulting is supported externally by flying buttresses, and there is an open triforium over the main arcades. Now the whole of this large church is decorated not only with arabesques and patterns, but with decorative pictures of the highest excellence. The decoration and pictures were both executed from sketches and cartoons prepared by M. Cuypers and his pupils.

An equally remarkable church is that of Eindhoven, which consists of a nave and aisles of five bays, western towers and spires, transepts, a chancel with a prettily-arranged chevet, and three apsidal chapels. The length of this church is 237 feet; width over transepts, 114 feet; width of nave and aisles, internally, 71½ feet; nave in the clear 33 feet; height of nave to brick vaulting, 71½ feet; height of spires, 244 feet. The interior of this church is really superb; the whole is a mass of decoration and painting. The portions of the building which are not painted, are executed in buff, red and black brick, arranged in bands and patterns. All the decoration is on a dead white ground. Below the windows and in the blank spaces above the altars are conventional arcades, filled in with decorative paintings, executed in a very severe style, consisting simply of strongly-drawn outlines, filled in with very flat washes of colour; the whole being kept in an exceedingly light key, and entirely devoid of

shadow; bands of white are also used amongst the brick work, and the general effect of the interior has a kind of opal hue, which is very charming. Every thing in the building is decorated with colour, even the stone altars and the parcloses of the choir, which are amongst the most successful designs for church furniture I have ever seen. All the windows are filled with stained glass, into which a great quantity of pure white glass is introduced. Until I saw this church I had no idea of the immense value of whitewash in decoration.

M. Cuypers' churches at Breda, Oudenbosch, and St. Willebrord at Amsterdam, are even larger than those I have already mentioned. The church at Breda consists of a nave and double aisles, a hundred feet wide over the whole, transepts, a deep chancel, and three spires. The total length is 216 feet, and the height of the spires 235 feet. It is a much plainer church than those already described, and not so satisfactory in design. The large practical triforium is also a mistake as far as effect is concerned.

The church at Oudenbosch is Romanesque in style, and extremely plain; it is at present only as high as the clerestory, but promises to be a very striking building. Its dimensions are, length, 260 feet; height, to ceiling of the nave, which will be flat and boarded, 65 feet; height to apex of octagon lantern, over crossing, 200 feet; nave, 40 feet in the clear. This church will offer a magnificent field for coloured decorations, as the windows are very small, and there are great unbroken wall spaces. This church is entirely of brick.

The church of St. Willibrord at Amsterdam is only just commenced; when completed it will have five spires, double aisles, transepts, and be over 300 feet long. At Sneek another church is now building, which will be 210 feet long. The churches at Alkmaar, Bodegraven and Klosterburen are all large and important buildings. M. Cuypers' churches have at first a singular appearance to an Englishman, on account of their excessive nationality; they are very square in composition, very regular, and much more plain externally than such buildings are with us; then they are all built of brick, with stone very sparingly used; then there is a lightness of construction which strikes an Englishman as being peculiar, but when one comes to examine them, and compare them with the ancient Dutch buildings, one is bound to acknowledge the thoughtfulness and thorough common sense of the design. Of course a church built with heavy columns and thick walls would simply sink through the soil in Holland, and the more lightly a building can be constructed, and the less material used in its construction, the more durable it is. I am sorry to say that the other Dutch architects who have taken up the Gothic style of architecture have not been so successful in their work as M. Cuypers, for although M. Weber, of Roermond, has built a very complete church at Mastricht, with a great stone rood-screen containing two altars in it, a sacramentshauslein, 30 feet high, a complete set of stalls, and all other ritualistic requirements, it is not, on the whole, a good church. Herr Van der Brinck has built many new churches, some of them nearly as large as those already described, but they are rather well-intentioned attempts than successful buildings. Herr Van Tolda has also built a vast number of churches, some of which, Helmond and Velemen, for instance, are of great size, over 200 feet long, and have a striking outline, but are ruined by their architects not understanding Gothic detail. M. Marjerij, a pupil of M. Cuypers, has built a very creditable church at Rotterdam; it is a large cruciform building, but must be considered a copy, on a smaller scale, of M. Cuypers' church at Vechel. A few examples of the eclectic school are to be seen in Holland, of which perhaps the least objectionable is a new Protestant church at Rotterdam. Fortunately, however, the Dutch have set their faces against eclecticism, and the Roman Catholic churches are nearly all built in the Gothic style, while the new Protestant churches which I have seen are either in the genuine old conventicle style, or the more objectionable churchwarden's Gothic of eighty years ago.

In this paper I have spoken strongly against eclecticism as practised in Germany, but I do not wish it to be understood that I am speaking against eclecticism in the abstract; were I to do so, I should be simply raising my voice against the inevitable, for, if architecture is to have a future, and if there is to be a new style, that style must be more or less eclectic—but what I do protest against is, that men who, without understanding the architecture of the past or present, should attempt to invent an architecture for the future; and I feel convinced that those designers who for many years past have laboured so hard to become thoroughly acquainted with the architectures of past ages, are doing far more to found a new style than those who, discarding all the experiences of their ancestors, try to evolve a new style out of their own imaginations. Those who have gone before us have left us three great styles of architecture—the Greek, the Gothic and the Renaissance—which are to architecture as the primary rays of light. The Gothic, with its golden excellence, is the yellow ray—the Greek, with its pure beauty, is blue ray, and the Renaissance, with its gorgeous splendour, is the red ray. Time alone can combine these rays, and make them daylight in the dawn of the real architecture of the future.

The PRESIDENT said, before I attempt to offer our thanks to Mr. Brewer for his exertions, I would express a hope that it may lead to some discussion which may continue the interest of this really valuable paper. Our friend Mr. Street will no doubt have something to say upon it.

Mr. G. E. STREET, Fellow.—I feel that great thanks are due to Mr. Brewer for his paper, but I am hardly prepared to follow it, because my own acquaintance with the works of modern German architects is much less than with those of their forefathers. It so happens, indeed, that my acquaintance with the subject begins just when Mr. Brewer leaves Germany for Holland. M. Cuypers, of Amsterdam, is an old friend of mine, and I saw him when he paid a visit to England some years ago, when he saw and studied many of our great old churches, and I think his study of our English work did him good. He certainly struck me as being a most able man, and also a very modest one. Herr Guldenpfennig's name is quite new to me, and his works appear to be particularly good. I attribute that not only to his talent, but to his luck. He has the good fortune to live in a region which rejoices in buildings characterised by better architecture than one commonly sees in Germany in ancient works. The Cathedral of Paderborn is a noble structure, as are also other extremely good buildings in the same district. I doubt not that a man locally educated and employed almost entirely in such a district derives benefit from being associated with such buildings which other architects have not the advantage of. The difficulties in the way of a revival of Gothic architecture in Germany are great, and must be looked at in connection with the old history of our art there. In the middle ages the Germans did not develop their architecture for themselves in the way French and English did. They went on practising their Romanesque style with little variation long after the rest of the world had discovered the use of the pointed arch. I have heard German buildings called Romanesque in this room, which are not so in point of age, but only in point of character. And it was not until near the fourteenth century, when the example of Amiens stirred Germany into rivalry and imitation at Cologne, that we see a sudden change, and in no sense a development of art, introduced in German buildings. The consequence is, that architects now-a-days all over Germany are taught, looking at their own country, that there are no examples of old architecture earlier than those of the fourteenth century which can be adopted as guides for what they have to do or to study, and this has had a most prejudicial effect upon the revival of Gothic architecture of Germany. In their great national works at Cologne Cathedral, you have that style in the highest degree of excellence, but its completion is not likely to be attended with the most satisfactory results, inasmuch as the complete work has a hardness and want of interest, which was hardly felt, or was at least forgiven, in the fragment which remained before the restoration began.

In Vienna as in Cologne, the same influence has been felt. The Votive Church which I went over four or five years ago in company with its architect, is an excessively able academical work, but not more than this. It appeared to me to want originality, and to be from beginning to end very German and hard in character, and very unlike the sort of work you would see in France or England under similar circumstances. It is an able work up to a certain point, but it has the misfortune of being founded upon nothing but the study of complete German pointed work, unaided by knowledge of thirteenth century art. I do not know whether this may not to some extent be laid to the circumstance, that German architects have been more fortunate than we have been in the possession of many ancient drawings and designs—such as those for Ulm and Cologne, the study of which may perhaps have affected not only their designs, but also the style of drawing which they have adopted. These old drawings are executed with thin unfeeling lines, and often in unsatisfactory perspective. That style of drawing is being departed from now, but still the drawings in many German illustrations of architecture are of an extremely disagreeable kind. They take no account of the lines or divisions of stone work, and tend to make buildings (which to begin with are like cast iron in their detail), look still more hard and uninteresting. Mr. Brewer has spoken strongly as to the condition of things in Munich, and I agree with him, that nothing more disagreeable can be conceived than much of the work there. The Eclectic work is bad, and the Gothic is worse. Four or five years ago, when I was in Munich, a large Protestant church was being built upon a design that one could scarcely conceive to be possible in such a place as Munich. Though, certainly in some respects, architects there seemed capable of descending almost to anything. I recollect in one great building in the Ludwigstrasse, the material used was not brick, but plaster, pointed and lined out in pencil to imitate bricks? We might well be proud that our member Mr. George Gilbert Scott, has the credit which Mr. Brewer has justly given him, of having been the first restorer of a better state of things in the instance of his great church of St. Nicholas, Hamburgh. For my own part, it has been sometimes a matter of regret with me, that before he made his design for that church he should have taken so much trouble to identify himself in the spirit of his work with the old German builders, seeing how little these had ever been influenced by the thirteenth century style; and perhaps he lost an opportunity of educating the Germans in something better than the best of their old buildings. I confess, in conclusion, that though I have travelled much in Germany, the modern works I have seen have been so distasteful to me, that I have hardly looked at them, and it is apparently only in one or two districts, according to Mr. Brewer, that any real Gothic beauty is to be found in the new buildings. And of these it would be hard to find better examples than the little grange and gateway which Mr. Brewer has described as the work of Herr Guldenpfennig. I am rather chary in endorsing Mr. Brewer's views with regard to the restoration of the east end of the Cathedral at Paderborn, inasmuch as the work, good as it is in itself, does not appear to me to be of the solid character which that magnificent church requires.

SIR M. DIGBY WYATT, Fellow, said:—I rise with great pleasure to propose a vote of thanks to Mr. Brewer—not only for having described to us a great number of beauties, but also for having waded through—which must have been a task of much suffering to him—an immense amount of bad architecture in searching for them. He has brought before us much that is valuable and interesting, and many signs of progress which it cannot but give us great pleasure to hear of; at the same time he has pointed out less pleasing characteristics in much of the architecture of Prussia and Germany with which every traveller must be more or less familiar. While recognising singular inequalities and not unfrequent shortcomings in the works of Teutonic ecclesiastical architecture, more particularly in buildings erected under "the powers that be," we ought not to forget how deep a debt of gratitude we owe them for the steady and honourable way in which they have sustained and maintained the old monuments of the

country. The good structural condition of the vast religious edifices at Cologne, and the restoration of the Cathedrals and Churches at Paderborn, Munster, Magdeburgh, Hildersheim, Ulm, Bamberg, Ratisbon, Wurzburg, &c. reflect great credit on the government, and have only been accomplished by the expenditure of a large amount of money, liberally spent, and energy admirably kept up. It is impossible, however, to view with equal complacency the great bulk of the modern buildings of Germany in which the mediæval styles have been affected. Although the students of architecture in Germany have the advantage of much freer access for purposes of study to the great works upon the ancient architecture of their country, and to the structures themselves, than our students generally have of theirs; it would seem that such opportunities have rather benefitted the *savans* than the architects. Heedless of special merits and qualifications for special work, the government have employed sometimes—but rarely—young and fanciful architects, who may have had "good friends at court," and at other times, indeed generally, dull old stagers, rising in turn to the top in official academic "promotion by seniority," to design the numerous works they have caused to be carried out. The result has been in too many instances architecture of a very poor and certainly monotonous kind. This is to be remarked particularly with regard to Prussia, where the same pattern of building in every village church is enforced. In obedience to the system Mr. Brewer has designated as "Ayrtonism," the architect is judged to be the best the cost of construction of whose buildings has been kept with in the smallest number of thalers. This vicious system has deluged Prussia with those numerous specimens of very bad modern architecture—of schools no less than churches—to which Mr. Brewer has drawn our attention. It is, however, pleasant to turn from what the governments has done, to the individual exertions of active and enlightened men of the country. The investigations and illustrations of Bock, Hefner, Reichensperger, Ansem, Werth, Statz, Ungewitter, Otte and others, have thrown much light upon the mediæval treasures of their native lands. Nor should we forget what was done in earlier days in the study of ecclesiastical archæology by Boisserée, Möller, Puttrich and others, in their illustrations of the ancient monuments of Germany. In Austria, the work of Von Eitelberger on the architecture of that empire is a very pleasing one, by no means executed in that weak and wiry style of drawing of which Mr. Street complains. In modern works the great breadth and simple grandeur of the monuments of the thirteenth century has been much lost sight of, though Germany, particularly at Treves, possesses some splendid illustrations of that style, more particularly the exquisite Frauen Kirche of the last-mentioned city. Another great impulse which has been given to the study and development of the excellencies of Teutonic mediæval art, has been the illustrations of its history by its monuments, by those worthy "nationalists" who contributed munificently to the formation of the admirable historical museums and collections at Nuremberg, at Berlin (in the Neue Museum), and at Munich, especially. The comparatively recent re-arrangements of other older museums and collections of all the detailed branches of ancient German art and industry, such as the Ambras Sammlung at Vienna, the Zwinger at Dresden, the museums at Darmstadt, Brunswick and Cassell, are of a most interesting character. If the German architects would but study the mass of information provided by the *savans* of their country, they would find themselves even better supplied with antiquarian information on their national arts than we—highly favoured in that respect as we are—have hitherto been. There is certainly no deficiency of architectural education in Germany, and it is only because, as I think, the government system has somewhat fettered the profession by a too rigidly academic education, that the German architects have failed in hitherto exhibiting a strong feeling for the re-development of their national architecture. I have no doubt, however, that in a little while we shall see some good monuments of ecclesiastical architecture in Germany, though the principal practice at present may seem to have been entrusted in most cases to comparatively young or prentice-hands.

Mr. H. DAWSON, Fellow.—I beg to second the vote of thanks to Mr. Brewer. I have only lately returned from Germany, and the impression on my mind with regard to Munich, corresponds entirely with what Mr. Brewer has stated. I would, however, remark, that there is now a municipal building in progress, viz., the new Guardhouse, with shops on the ground story, at the corner of the Marien Platz, which shows that there is some breath among the dry bones. I cannot at the moment recollect the name of the young architect, but perhaps Mr. Brewer may be able to tell me. Instead of being built of the common material of Munich, viz., bad bricks covered with stucco, and in that stereotyped crude style which offends the eye everywhere, it is a fine Gothic building in hard demi-glazed red bricks of good colour, with a warm durable stone. The design has much vigorous and original treatment, and although not perfectly satisfactory in all its details, it will bear favourable comparison with many of M. Cuyper's works. I think it is almost the only good modern Gothic work to be found in Munich. This admirable red brick is much of the same nature as that manufactured by Mr. Blashfield, and which Mr. Charles Barry used in the new Dulwich College. I am happy to say it is being used in many of the new buildings, and bids fair to get rid of that abominable stucco which one sees all over Germany. Speaking of modern Munich, I think that as the Germans until recently did not appear to possess an architect competent to conduct a revival of the best schools of architecture, and were specially ignorant of Gothic art, the late king and his counsellors acted wisely in lining the new streets of the city, such as the Ludwig Strasse, with copies of the good cinque cento buildings of Italy, mostly constructed of stone and brick, and infinitely preferable to those abominations in stucco to which I have referred. I regret however to state, that side by side with this fair promise of good work, I noticed in the renewal of several of the larger buildings, that the stucco fronts were coloured and jointed in imitation of these new red bricks, and so wonderful is the imitation in the various shades of the brick, that from a little distance it is impossible to detect the counterfeit. Doubtless, the Munich workmen are masters in colour, but this mode of architectural decoration is simply atrocious.

Referring to Ratisbon, I should like to know whether Mr. Brewer visited a little church situated close to the south-east of the Cathedral and known as S. Ulrich, orthe Alte Pfarr Kirche. It is an interesting example of the transition from the Romanesque to Early Pointed. By the internal columniations the centre forms nearly a square with a small sacrarium having an ancient stone altar, and it is surrounded on the west, north and south sides, with stone galleries resting on stone and brick vaultings, which galleries, tradition says, were occupied by the *noblesse* of early days. The details are unique and interesting.

Mr. E. I'ANSON, Vice-President, said:—I desire to add my tribute of praise to the excellent paper we have heard. Mr. Brewer has described with great vivacity and vigour the composition of some of the architecture, but is he right in saying this eclectic architecture of Munich is a mixture of so many styles as he enumerates? My own impression is, that it is an adaptation of Byzantine architecture, in the same sense as we thirty or forty years ago in England adopted Greek architecture. The Germans adopted the simple form of Byzantine architecture, one of the simplest it was possible to cultivate; and I venture to think the modern eclectic school of Munich architecture is founded upon Byzantine architecture exclusively. The cultivation of that style, however, has been by no means successful, and has produced throughout Germany a vast number of most unsatisfactory works; but there are some exceptions. I recollect a very fine Byzantine church in Munich, and I also remember another in the form of the Roman Basilica at Berlin, treated quite in the Byzantine style, which I think is good of its kind; but generally the result of this aim is not satisfactory. It is interesting to hear what Mr. Brewer has said of the progress of our art in Holland. It is more than twenty years since I was there, and I recollect at that time the churches were of the baldest and meanest character, and all

were indiscriminately whitewashed, which produced a very monotonous unarchitectural effect. It is satisfactory to hear from such an observer as Mr. Brewer, that the Dutch have in the last twenty years made such progress in their architecture.

Mr. G. E. STREET.—I wish, with your permission, to add a few words with regard to the revival of stained glass in Germany. That perhaps is the only point in the whole subject which really concerns us in England. It concerns us, inasmuch, as it has already succeeded in destroying the effect of Glasgow Cathedral, and is, unless interfered with, likely to do so in St. Paul's also. There are some people who suppose that Munich glass is good for mediæval buildings, because the manufactory was first started in connection with the Au-kirche and other revivals in Munich; but I think its fitness for the purpose may be judged of very completely from what we see here and at Cologne. Its design and manufacture seem to be against every canon which one could make for the treating of glass for windows, and it is in all respects infinitely worse than the glass which we may get here. Nowhere can one better see the difference of effect in Munich glass as compared with what is to be seen in good ancient examples, than in the nave of Cologne Cathedral. Here the south aisle windows are of Munich glass, the north aisle of old glass of the fifteenth or sixteenth century. The former are garish and disagreeable in colour, and unsuitable in design; the latter as brilliant and beautiful as glass can well be; and I should esteem it a great misfortune, if after such a paper as we have heard to-night, nothing were said to show that we as British architects protest against the use here of Munich glass.

SIR DIGBY WYATT.—We should also enter our protest against the treatment to which many interesting specimens of mediæval mural painting have been subjected. This is strikingly illustrated in the so-called restorations of the beautiful thirteenth century polychromatic decorations at Brunswick and Hildesheim. In looking at different portions of them, the spectator may say of one, "this is old"—of another, "perhaps this may be old"—and of a third, "well, that looks modern, whatever it may be." The truth is they are all "touched up." The substantiality of the monument, and its integrity and interest for purposes of study, are lost altogether. Even in such attempted "putting new wine into old bottles"—if, Sir, you will pardon the quotation—when anything new is introduced, it is of that stilted, hard, modern style, which in nowise harmonises with mediæval work. This is a subject for much regret, that with probably the best intentions, the Germans seem to be getting into the way of destroying what is really most interesting in ancient mural paintings, *i.e.* their former integrity as illustrations of the history of the art of painting in its association with architecture.

Mr. A. WATERHOUSE, Vice-President.—I could have wished that Mr. Brewer, in his interesting paper, had told us more about what is going on at Vienna. I paid this city a hurried visit last summer, and it seemed to me there were wonderful opportunities open to the Viennese architects, of which they appeared to be making good use. As far as Gothic architecture is concerned it would seem to be almost wholly in the hands of two men, the principal of whom is Schmidt. I believe the grand Votive Church is Ferstel's only work of note in the Gothic style; but Schmidt is working very extensively in that style: to wit, the restoration of St. Stephen's Cathedral, the new Town Hall about to be commenced, and several churches. Though his work may be liable to some of the faults attributed to all German work, it shows great originality of plan, and consequently in the general outline and appearance of his buildings. There is one church in particular which he is about finishing in the district of Fünfhaüsen, and which I see is illustrated on the walls. This church is polygonal on plan, dómed, with a high pointed slate roof on the vaulting, is surmounted by an ambulatory, and has two western towers, connected by bridges with the outer gallery round the drum of the dome. The whole group externally, with its sacristies and side chapels, is exceedingly picturesque.

There is one thing remarkable about the work of these Vienna architects, they almost always work more or less in brick, and succeed in getting it set with joints three-eighths of an inch in thickness, and three-sixteenths back from the surface. The effect of this is most satisfactory.

The PRESIDENT.—I have now only to convey to the gentleman, who has favoured us with this able and entertaining paper, our best thanks, and to remind the members that it comes from an amateur, who has evidently made himself master of the technical part of his subject, and whose remarks will carry great weight. They have led to a most interesting discussion. To my mind it is very gratifying, since it confirms the views I myself entertained of the buildings which I saw in the spring of this year. It was with the greatest pleasure that I heard Mr. Street rise to protest against that most objectionable Munich glass. I trust we have seen the last of it in this country. I have great pleasure in conveying the thanks of the meeting to Mr. Brewer, and I hope he will, as opportunity occurs, favour us with other papers of a similar kind to this.

Mr. BREWER, having acknowledged the compliment paid him in the vote of thanks, said,—There is one remark I would make as to the style of brick-work which Herr Schmidt was able to get executed in Vienna. I have noticed the same style adopted in the works of Guldenpfennig, and I have also noticed that in his brick-work he has left the put-log eyes open. I do not know that there is any advantage in that beyond its obvious convenience, but certainly, when repairs are being carried on, it seems absurd to knock out a series of holes for the scaffolding, whereas if the put-log eyes are left open, it can be done with the greatest ease. With regard to the church at Ratisbon mentioned by Mr. Dawson, I believe that church was illustrated in the proceedings of this Institute in connection with the paper which I had the honour of reading at this Institute some time ago.* It is a most remarkable building, and worthy of study in many respects.

The discussion having been thus brought to a close, the meeting adjourned.

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* "On the Mediæval Architecture of Central and Southern Germany," by H. W. Brewer, Esq., read at the Ordinary General Meeting, on the 16th of March, 1868.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 4th Dec., 1871, the following Paper was read—
EDWARD I'ANSON, Vice-President, in the Chair:—

THE BRIDGES OF LONDON.

By HENRY CARR, Member Institution C.E.

THE request to furnish a Paper on "The Bridges of London" is willingly complied with as far as ability and circumstances permit; but the subject is a wide one, and is not to be satisfactorily compressed into the short compass of a mere Paper.

The Bridges of London may be considered,—

First.—Historically as connected with the varying circumstances of the Metropolis in early and later times.

Secondly.—Simply as means of communication considered with reference to the localities on each side of the river, and to the traffic as developed by increased population and trade.

Thirdly.—As mechanical structures solely with reference to strength, stability and efficiency for the duty required.

Fourthly.—As architectural works in the more common acceptation of the term, that is, as works of art.

Those who wish to study "The Bridges of London" historically, cannot do better than commence with the "Chronicles of London Bridge" by an Antiquary. In that work there is a mass of interesting information, interesting to architects and engineers as well as to antiquaries.

One of the diagrams before you has been prepared in order to give a general view of the progress of London from the Conquest to the present time.*

During the Saxon reigns, it seems clear that a timber bridge was carried across the Thames about the site of the present London Bridge. This timber bridge was frequently wholly or partially destroyed. It was washed up, pulled down by the Danes, and burnt more than once; but was constantly renewed and maintained until the original stone bridge was built, which occupied no less than thirty-three years in its construction, from 1176 to 1209. On the first building of a stone bridge at London, a sort of crusade was preached by Peter of Colechurch, who went about the country with a brief, and collected funds for its erection.

From the earliest period it appears that premises in Tooley Street, called the Bridge-House Yard, were appropriated to the stowage of materials and general purposes of works connected with London Bridge, hence the origin of the name of the now well-known "Bridge House Estates' Committee."

* This diagram illustrated in chronological order the additions to bridge accommodation with reference to the gradual increase of population in London.

In 1213, King John ordered the Corporation to repair the bridge. This shows how soon repairs were required, four years after completion. It also shows that the bridge was then in the hands of the Corporation.

In 1249, Henry III. quarrelled with the City, and took the income of London Bridge into his own hands, the receipts to be paid into his exchequer.

In 1252, there is a deed referring to the "*Protection for the Brethren of London Bridge, their men, lands, goods, rents, and all their possessions.*" This it is presumed was the "Bridge House Estates' Committee" of that day. Evidently under the Corporation as at present.

At a very early period "The Bridge House" was used to stow corn during times of famine, and ovens were then erected for baking for the poor.

In 1491, mention is made that "the bridge master is some freeman elected by the City, and set over the Bridge House to look after the reparations. A good salary allowed."

In 1594, the City companies were ordered to lay up corn in the Bridge House. Admiral Hawkins demanded corn and the use of the ovens for his fleet. The demand was successfully resisted by the Corporation.

In the years 1465-1482 and 1506, the expenditure on the bridge and the rentals seem to have been from £650. to £815.

In the years 1533 to 1664, the rentals ran up from £840. to £2,054.

In 1727 to 1753, the rentals were from £3,299 to £3,843.

The Bridge House Estates are now held by the Mayor and commonalty and citizens of the City of London upon trust for the maintenance of London Bridge, and are managed by a committee appointed by the Court of Common Council out of the members of that body. The titles to the property belonging to the Bridge House Estates are very numerous and ancient, the land being granted or devised by kings of England and "charitable and well-disposed persons." Some parts of the estates are subject to payment of small annual quit rents; and other parts were, before the Reformation, liable to the expense of performing certain masses and other religious ceremonies.

In addition to the maintenance of London Bridge, the estates are also liable to the support of two bridges at Stratford, namely, St. Michael's and Peg's Hole Bridges.

The expense of repairing old Blackfriars Bridge and erecting the new one were charged upon the revenues of the estates by Act of Parliament.

In 1632, and again in 1638, there appear to have been great fires in the houses on the bridge. The traffic must then have been very small, or these fires would have suggested the clearance of the houses altogether.

On the 4th February, 1641, "There flowed two tydes at London Bridge within the space of an "houre and a halfe, the last coming up with such violence and hydeous noyse, that it not only frightened "but astonished above 500 watermen that stood beholding it on both sides the Thames, which latter "tyde rose six feet higher than the former had done, to the great admiration of all men."

A very similar occurrence took place during the re-building of Blackfriars Bridge, but not to the same "*hydeous*" extent, rather astonishing but not "*frightening*" the beholders.

The general view of the importance and public advantage of the means of communication by London Bridge is shown by an Act passed in 1693. The *Bridge* is classed with *Hospitals*. The sentiment is the same as that in the earliest times, when the maintenance of the passage of the Thames was accounted a pious work.

This Act was passed, laying charges on City property, "*but Hospitals, London Bridge and such places as were liable to its repair were exempted.*"

In 1701, a list of rooms and offices, bought and sold in the City of London is given, the total amount to £145,586., amongst these occur the following:—

A clerk of the Bridge House	£1,250
2 Carpenters, each	200
1 Mason	200
1 Plasterer	200
1 Plumber to the Bridge House	250
2 Porters to the Bridge House	200
1 Shotsman of the Bridge House	200

The plumber's place being worth £50. more than the mason's or carpenter's, looks very much as if lead was purloined in those times as well as at later dates.

The reading of this list rather suggests the thought of abolition of purchase in the army, the question of the present day. We are not yet altogether clear of such transactions.

It was not until 1685, four hundred and seventy-six years after the completion of the original stone bridge, that the first widening took place; the obstructions appear then to have been cleared to a certain extent, increasing the width of roadway from 12 to 20 feet.

After a period of sixty-five years Westminster Bridge was built. The question of a bridge at Westminster had indeed been mooted in the reign of Charles II., a hundred years before, but the project was opposed by the Corporation as likely to injure the interests of the City to a most alarming extent. In fact it was said "London would be destroyed if carts were allowed to cross the Thames elsewhere." The rich city prevailed with the money-spending monarch, and the bridge at Westminster was postponed for three generations.

In 1760, a period of ten years only having elapsed since the opening of Westminster Bridge, the houses on London Bridge were entirely removed, clearing the roadway to 43 feet, as measured on Dodd's plans, prepared for Parliament, 1799.

In nine years more old Blackfriars Bridge, 45 ft. wide, was opened.

Waterloo, 42 ft. wide, in 1817.

Southwark, 42 ft. wide, in 1819.

New London Bridge, increase 11 ft. over the old, in 1831.

New Westminster Bridge, increase 42 ft., in 1862.

New Blackfriars Bridge, increase 30 ft., in 1869.

The diagram already mentioned will shew at a glance more clearly than any words, how rapid was the increase of bridge accommodation after the first widening of London Bridge in 1685. For 476 years a roadway of 12 ft. or thereabouts sufficed, a narrow dark passage between the two rows of houses.

In less than 200 years the increase of bridge accommodation has been from 12 ft. to an aggregate of 419 ft.

More time cannot be given to this head, though the details of the original wooden bridges, the construction of the stone bridge, the contracted waterway and dangerous "shooting of the bridge," the waterworks, the construction of the temporary roadway across the sterlings at the time of throwing the two centre arches into one, its conflagration, rebuilding in a month, and many other details would be of much interest, to say nothing of the many points of interest connected with the bridges of later times.

Secondly.—"*The Bridges of London considered simply as means of communication.*"

The question of communication between the north and south sides of the Thames at London, always has been, and always must be, a matter of the greatest importance. It is now a question of some difficulty on account of the great accumulation of business at the east end, considered in connection with the very large traffic on the river up to London Bridge. The two great traffics by land and water as it were overlap. Bridge communication is much wanted in the neighbourhood of the Tower; the great river traffic, however, will not admit of interference below London Bridge, except at enormous cost. High level bridges have been proposed, a tunnel has been constructed, but still the traffic from the east of London Bridge comes to that crowded thoroughfare, and there is no immediate prospect of any change in that respect.

Much has been said lately and proposed with a view to widening London Bridge, but the difficulty is not so much on the bridge itself as in the approaches—the object should therefore be to divert traffic westward as much as possible, thus relieving the easternmost bridge by diverting that traffic to the west which might go westward. The mode in which this might be accomplished will be alluded to presently.

If it be determined to widen London Bridge, it should be so done as not on any account to interfere with the general elevation, any addition by iron-work would be a barbarous proceeding, destroying the effect of one of the finest bridges in Europe; and, moreover, as before stated, such addition to the bridge would not relieve the approaches which are as objectionably crowded as the bridge itself. Again, the foundations of the bridge would not admit of more weight being put upon them—that objection would be fatal to several plans which have been proposed.

One suggestion, which has been for some time before the Bridge House Estates' Committee, is shown by the two plaster models—this plan is considered as the utmost that should be attempted; the addition would be 27 per cent. to the foot-path, a valuable increase, as would be evident to any one watching the southern railways when pouring their thousands into the city in a morning. This suggestion would not interfere with the general elevation of the bridge as seen from the river. The proposal is to thrust the parapet somewhat over on to the cornice, and to make it as thin as granite will admit of being worked and fixed with safety. The foot-path is now 9 ft. in width, the addition would be 2 ft. 6 in. on each side, thus making the footways 11 ft. 6 in.

However, as said before, the great object should be to lead the traffic westward, which can only be done by improving Southwark Bridge. There have been three great objections to the use of Southwark Bridge.

First the toll, that is now done away with.

Secondly, the want of good access both north and south, New Southwark Street on the south and Queen Victoria Street on the north have obviated this difficulty.

The third objection to the use of Southwark Bridge is the steep approach and narrow width—this is the point still to be dealt with.

It is proposed to take down the existing cast iron arches, and to substitute arches of wrought iron; by this change of construction the thickness of arch and road material might be reduced from 9 ft. to 5 ft. 6 in. It is proposed also to reduce the headway underneath from 29 ft. 6 in. above Trinity highwater to 25 ft., making it the same as under New Blackfriars, the summit level of the roadway would thus be lowered 8 ft., which would admit of the gradient on the south side being reduced from 1 in 26 to 1 in 43, and on the north approach from 1 in 20 to 1 in 40—1 in 40 being the standard of good gradient fixed by the Bridge House Estates' Committee for New Blackfriars.

In altering the arches it is proposed to corbel out the foot-paths, increasing the width of the bridge from 42 ft. to 54 ft., thus making it the same as the present London Bridge.

The nearest route from the Bank to the Elephant and Castle is over Southwark Bridge; if, therefore, the approaches were made good and the width of the bridge increased, it is felt that a considerable proportion of the London Bridge traffic might be thus drawn westward.

There is a curious fact regarding tolls illustrated by a circumstance in connection with this bridge. The bridge was thrown open, toll free, on the day of the entry of the Prince and Princess of Wales into London, and some little pains was taken to advertise the fact; a large traffic came over on that day, and such a permanent increase of traffic continued as to raise the dividends 33 per cent., till the tolls were finally abolished. After long negociation an arrangement was effected with the City authorities to throw open the bridge, toll free, for a year as an experiment; it being well known, on the part of the Bridge Company, that when once thrown open toll free, it could never be closed again.

The bridge cost £660,000 cash. The value of the bridge at the time of sale, arrived at by capitalizing the income at 5 per cent., would be £60,000, the sale was effected at £200,000.

To say nothing of the value of the bridge itself, equally good approaches could not have been purchased and cleared in any site so suitable for less than a million, the bargain may therefore be considered a fair and good one for both parties.

It is no doubt desirable that Waterloo Bridge should also be thrown open toll free, but though the original shareholders have never received any dividend, the annuitants are in receipt of a very considerable income, to buy off which, and to pay the original shareholders something, would amount to a very considerable sum—far more than at present there is any prospect of being given by parties interested in this locality, which is beyond the reach of the City purse.

The rebuilding of Westminster Bridge of a width of 84 ft. has provided ample accommodation there. It may be regretted that the inclination on the bridge itself has not been made a little steeper, in order to ease the approaches; the gradient on the bridge itself is 1 in 58, and the approaches 1 in 30 at the steepest part, whereas a general inclination of 1 in 43 would have been more advantageous for the road traffic, without interfering to any appreciable extent with the river traffic; the approaches have been somewhat sacrificed to the bridge, instead of considering the whole as one work, and giving the best possible inclination throughout.

Lambeth Bridge was built to meet a supposed want, but it is singular how little traffic there is really found to go over. From parts of Pimlico to the City this bridge offers a good route, but the traffic from Pimlico to the City is very small, and with an Englishman's inveterate objection to tolls, the route by the Thames Embankment no doubt takes the bulk of the passengers who do not go by omnibus.

Vauxhall Bridge occupies a site of considerable importance, and though it is on the outskirts of the metropolis, a fair amount of traffic from the west end to the south of the Thames takes this route. The extension of the South-Western Railway to Waterloo Bridge, and lately the formation of the southern embankment from Vauxhall to Westminster Bridge, has caused a very severe loss to this Company.

Chelsea Suspension Bridge is a valuable communication for residents in the adjoining localities, and will probably become of increased importance as the southern side of the river becomes more populated, and every year as building increases, free access to Battersea Park becomes the more desirable; but still this bridge, though no doubt one of "the bridges of London," can hardly be considered as taking part in the great metropolitan traffic.

"The Bridges of London" considered as mechanical structures, with reference solely to strength and stability, will lead naturally in the first instance to the question of foundation.

The original timber bridges which crossed the Thames at London towards the end of the Saxon reigns and the beginning of the Norman are involved in much uncertainty, but there seems evidence of examples of the importance of driving the piles of such bridges deeper than was then accomplished, for they were washed up by floods, and pulled out by the Danes to a very serious extent, carrying with them the superstructure.

The defect of these piles probably led the builders of the first stone bridge into the opposite extreme, namely, making the piers too massive, and by their very mass intended for strength leading to destruction by increased scour. The preservation, maintenance, and extensive repairs of the first stone bridge appear to have been a serious difficulty, and constant expense from the very date of its completion. The foundations were in fact defective from being too wide. The depth of piling might probably have been sufficient, had not the waterway been blocked up by the great width of pier, thus causing scour.

The piles of the first wooden bridges were not stable; the foundations of old London Bridge were not altogether successful, therefore in building the next bridge—Westminster, another plan was tried, the French system of caissons; in fact, barges in which the piers were partly built while floating, then sunk in place and the sides removed, the site having been dredged to receive them. The objections to this plan are that a perfectly level bed cannot be obtained, and the caisson bottom must inevitably rest in the first instance on limited portions: increased weight and time will no doubt produce a more even bearing, but it must involve settlement to some extent.

This caisson system was adopted at the next bridge built—Blackfriars; the caisson bottoms or platforms on which the piers stood, lately taken up, were 88 ft. by 37 ft. and two baulks and a half thick; area 3256 feet, bearing a weight of about 11,241 tons or 3½ tons per foot super, supposing the whole area to take its share of load equally; but in fact the weight was carried by a much more limited area, the load per foot on the surface of timber area or footing was about 6 tons. The timber projecting beyond the footings could not have taken any material weight. Had this weight been evenly distributed over the whole bearing surface, that surface being the London clay, or gravel resting on the clay, the foundation might have been good enough as long as not undermined, but there were symptoms of the arches having yielded on the centres being struck, which leads to the suspicion that the pier foundations had slightly moved, in fact, had come to their bearing as the increased weight came on. In arches Nos. 5, 6, and 7 from the south, lead was found run into joints on the north side, all three arches evidently having lurched over to the south, opening the joints on the north haunch. Lead was run in as much as an inch thick at extrados tapering inwards, the masonry joint being tight at intrados. The opened joints were not in one course through, but stepped a course up or down. It is supposed that some four or five tons of lead were taken out, but the greater part was stolen. This system of caissons is now universally admitted to be defective and inefficient, principally from liability to be undermined by increased scour.

Next in order comes Waterloo Bridge, the first of the bridges built in what may be called the present day, built after the date when engineering had become a distinct profession. The foundations of this bridge were of a totally different character from all preceding, no pains or expense were spared, everything was done which at that time was considered most efficient. Coffer dams of double piling and puddle were formed which did their work most successfully, laying the foundation dry. Southwark Bridge followed on the same principle, and new London Bridge immediately after.

Taking the case of London Bridge, the area of the pier foundations was laid dry with coffer dams

43 feet below Trinity high water, bearing piles of whole balk were then driven over the whole space, 4 ft. and 3 ft. 6 in. apart, cross cills were laid on the pile heads, the intervening spaces were filled in with rubble and brickwork, the whole planked over, and the piers built on the foundation thus prepared. The weight on the foundation of a central pier is about 21,151 tons, supposing this to be evenly distributed over the whole of the bearing piles, there would be a weight of about 88 tons on each pile, and of course, on each cill crossing each pile head. The specification describes these cills as either elm or fir. The sample of timber representing a pile head and cross cills shows what the effect would be of a weight of 88 tons on each pile. The cills were crushed at 30 tons. Clearly they could only support a very small portion of the 88 tons. The bridge therefore no doubt rests principally upon the intervening spaces which had been filled in with rubble.

Supposing the weight evenly distributed over the whole area of ground, it would be six tons per foot, and this weight the London clay seems just capable of bearing; but it is a question whether the solid clay undisturbed in its natural condition would not have been far more secure than when broken up by driving the bearing piles. The London clay is not a spongy material requiring piles to consolidate it.

It is well known that the courses of the piers have a downward tendency towards the east about 10 inches, and the eastern side of the superstructure has the same tendency, but not quite to the same extent, the average is about seven inches. The number of arch stones fractured would lead one to suppose there had been motion on the piers receiving their load; but on the other hand, the recorded small subsidence of the arches on striking the centres, indicates the contrary.

The inclination of the courses is accounted for by one engaged on the works thus:—

" Denmark Hill, April 15th, 1869.

" My dear Sir,

" I have much pleasure in being able to give you the information you desire. There never was any settlement of the piers of London Bridge. I made the drawings of that bridge for Sir John Rennie. Messrs. Jolliffe and Banks were the contractors; their principal master of the works was Mr. Henfrey, who was a very competent person. He had a young man with him, Mr. Hollingsworth, a relative. The foundations were constructed in coffer dams, and the pumps fixed at the down stream end, the piles driven, and the platforms were laid with an inclination towards the pumps.

" The stone was dressed in courses at the Isle of Dogs, brought up and laid with that inclination, Mr. Henfrey, intending to change the incline courses into horizontal before they approached low-water mark, but he died; and young Hollingsworth took the initiative, and did not discover the error before it reached the springing. He no doubt gained what he could afterwards.

" I am, my dear Sir,

" Yours very faithfully,

(Signed) " E. W. Morris.

" Henry Carr, Esq."

There are difficulties in this explanation, more particularly as regards the fact that all the piers would not be in same stage of progress at the same time, nevertheless the letter from one engaged on the works is of interest.

Sir John Rennie, the engineer, considers that a slight subsidence did take place in 1829, when the bridge was in progress. It is strange, however, that all the piers should have gone in the same direction, and nearly to the same extent.

In New Westminster Bridge another plan of foundation was adopted resembling that in building old London Bridge, the object in view being to avoid the expense of coffer dams. The principal

bearing is on 145 elm piles in each pier, driven 3 ft. 3 in. and 2 ft. 6 in. centre to centre, and cut off below low water. These elm piles are surrounded with 44 iron piles, 5 ft. centre to centre with cast iron plates driven between the piles, thus forming a complete casing which surrounds and includes the elm bearing piles; the interstices are filled in with concrete, making the whole solid.

The weight on these piers is so slight, when compared with that on the piers of London Bridge, that the question of foundation becomes of less moment. The weight per pile is about 15 tons, supposing the elm piles to carry the whole weight, or about 11½ tons, supposing the iron piles to take their share. Much the same question will arise with regard to these foundations as in the notice of London Bridge. There is an outer casing of cast iron, the interior filled in. Query, would not solid cement concrete resting on a well prepared bed have made a more efficient and more durable foundation than piles of timber, the interstices only filled in with concrete. Homogeneity is the essence of strength, one homogeneous mass is the true foundation wherever it can be obtained.

The next system of foundation introduced was that of iron cylinders open at bottom and sunk into the bed of the river by excavating inside first by divers; afterwards, when water tight, strata are reached by pumping out and working dry; the interior, when a sufficient depth has been reached, being filled solid with concrete or brickwork.

The railway bridges—Charing Cross, London Chatham and Dover, and Cannon Street are thus carried, the weight per foot on the bearing area varying from about five to seven tons. The testing weights showed that foundations so heavily loaded have quite as much to do as they are prepared to take. The Charing Cross piers having subsided 3 and 4 inches with the testing loads.

Nothing can exceed the facility of putting down such cylinder foundations, and nothing can be better where sufficient area is given, and where such form is suitable to the superstructure. The weight required to sink these cylinders seems to be about 3 tons per foot of circumference; that weight including the cylinder itself and the load placed on for the purpose of driving it down.

There is one interesting circumstance with regard to the cylinder foundations of the London, Chatham and Dover Bridge. The cylinders were 18 ft. diameter: it was desired in six cases to give a more extended bearing area; the excavation was boldly and successfully carried down 5 ft. below the cylinder bottom, and the diameter of excavation was extended from 18 ft. to 21 ft., increasing the area 36 per cent. The cylinders were relieved of the weights used to sink them before being undermined; but no support was required to carry the cylinders, nor was any timbering requisite in the space excavated. This is a good illustration of the solidity of the London clay.

There is one very important distinction between railway and road bridges. *In Railway Bridges* the weight is always carried in the same position, and is naturally transferred on to definite and distinct points; circular cylinders placed under these terminal points of the arch or girder become therefore suitable foundations. But the case of a road bridge is different, inasmuch as the varying traffic is distributed indiscriminately all over; the weight and strength of the bridge have, therefore, to be distributed also over the whole width, and consequently a continuous pier is more suitable than such isolated columns as are sufficient for railway bridges.

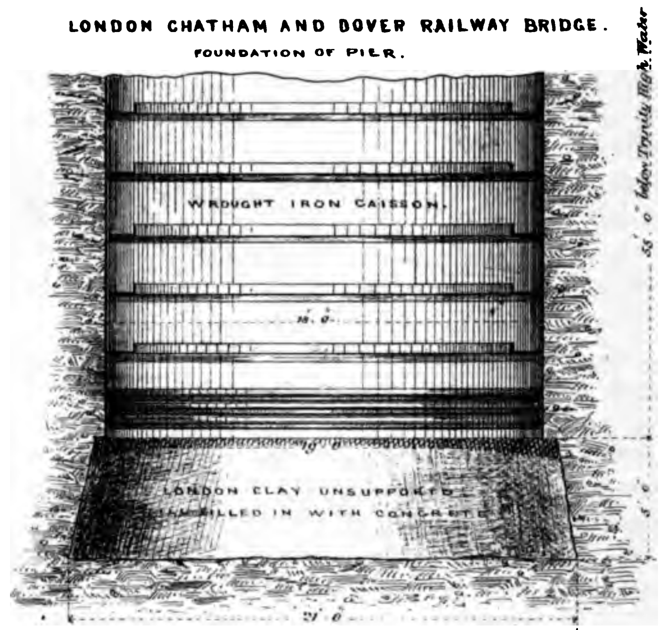
The suspension bridges at Chelsea and Lambeth follow suit with the railway bridges. Suspension bridges are similar to those carrying railways in having the weight collected and borne by few distinct and isolated points, the chains acting in that respect in the same manner as girders. Circular cylinders in road suspension bridges are therefore suitable for the same reasons as in railway bridges: the weight is accumulated on certain definite, distinct and isolated points.

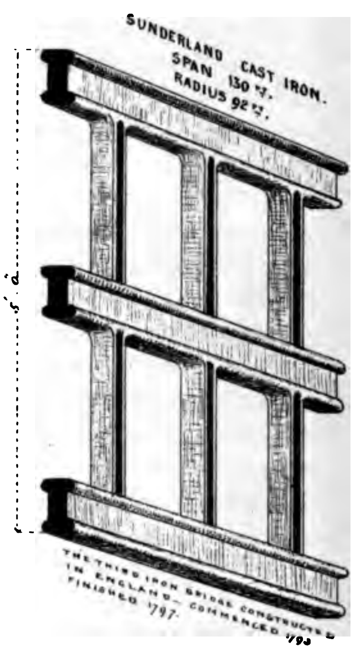
In re-building Blackfriars Bridge wrought iron caissons were adopted, varying, however, very materially from those used in the piers of the railway bridges. Each pier was formed by four

THE BRIDGES OF LONDON.

DIAGRAMS OF ARCHES AND FOUNDATIONS OF L.C.& D. RAILWAY BRIDGE.

LONDON CHATHAM AND DOVER RAILWAY BRIDGE.
FOUNDATION OF PIER.





SCALE TO ARCH RIB SECTIONS.

Photo-Lithod for the R.I.B.A. by Whiteman & Bass, London.

rectangular caissons 36 ft. by 18 ft. carrying the roadway, and two triangular caissons projecting beyond and carrying the cutwaters. A space of 3 feet was left between the caissons, which space was eventually filled with concrete and bridged over by the masonry at a level of 4 feet below low water, the pier being continuous from that level upwards.

The two piers on the Southwark side are carried down to 42 feet below Trinity high water; those on the City side, where the strata are softer, are 47 feet. The instructions received from the Bridge House Committee, were to put in such foundations as would admit of the river being dredged to 30 feet below Trinity high water, or 4 feet lower than the then existing deepest part. The new piers are 14 feet and 19 feet deeper than the deepest of the old foundations, and are all well into the London clay. The lower part of the caissons up to 4 feet below low water, which are filled in solid with concrete and brickwork, are left in permanently; the upper parts were removed as the work proceeded, the masonry piers commencing at the above-mentioned level, and the width being reduced from 36 ft. to 22 ft. 9 in. for the smaller, and 26 ft. for the larger piers. The area of bearing surface is 3739 feet, and the weight carried by the middle piers is 3½ tons per foot super, resting on the clay, which is about half the weight per foot on some of the railway circular cylinders. On an isolated foundation, where slight settlement would not affect or endanger the super-structure, a far greater weight may safely be placed than could prudently be trusted on a similar area forming part of the foundation of a large and continuous super-structure, such as the piers of Blackfriars' Bridge, where slight settlement of any one portion would have disturbed and fractured the masonry above.

In the upper portion of the piers of bridges there is not such scope for variety as in the construction of foundations. For the Thames, the right material, no doubt, is granite, and the best hearting is good sound brickwork. Good sound brickwork carefully built in Portland cement or lias lime is stronger work and more solid than even ashlar throughout, but the granite facing must be well bonded in, not such work as is sometimes done—a face carried up of stone nearly of the same depth throughout.

The arches of all bridges of any size or importance, up to a late date, were always of masonry; but after various examples of iron had succeeded elsewhere, cast iron was used for the arches of Southwark Bridge. In later times the manufacture of wrought iron has advanced so rapidly, and wrought iron offers such advantages over cast, that it is now almost universally used.

The cast iron arches of Southwark Bridge certainly are a bold and noble construction. It is a singular and almost unique fact with regard to cast iron arches that they were in the first instance made much slighter than in later works. The bridge at Sunderland of 236 ft. span has arches of about 46 inches area of metal. Southwark Bridge centre arch of 240 ft. span has arches of 6 ft. depth and 122 inches area.

The tendency in all other works has been to give greater mass in the first instance, and to build slighter in later times. The builders, however, of Sunderland Bridge gave their successors no opportunity of paring down, the margin of stability there was small indeed.

The danger with cast iron in general, and cast iron arches in particular, is that of getting an unequal bearing either from defective fitting, or from expansion and contraction. The rise and fall of Southwark Bridge arches is about 1 in. for ordinary change of temperature, or about 1-40th in. for each degree, such rise and fall must produce considerable variation in the load to be sustained by the extrados and intrados of the arches.

The brittleness of cast iron, together with the improved facilities for the manufacture of wrought iron, have led to the almost universal adoption of wrought iron for arches. If one portion of a wrought iron arch, say the intrados, should from bad workmanship or other cause have more load to carry than

the strength of the metal will bear, a general compression would take place in that portion, and a corresponding shortening, allowing the remainder of the arch (the extrados) to come into play before any mischief took place.

Though cast iron in the dimensions usually experimented upon, has probably double the power of resisting compression that wrought iron has, nevertheless it is usual not to trust it with much more than about half the load, showing how strong is the general feeling of distrust in that brittle material.

As regards oxidation, however, the balance is much in favour of cast iron, both from a less tendency to rust and also from the same absolute amount of loss being a less percentage on the greater mass. This is a strong reason against using thin wrought plates in any construction exposed to the weather—the loss, say of 1-8th in., by oxidation would be immaterial in a thick casting, but would be fatal in a quarter-inch wrought plate.

This question of rust was most carefully considered with regard to Blackfriars Bridge but no satisfactory result was arrived at. A plan of dipping the iron hot into a bath of prussiate of potash and chloride of potassium, and further treatment with cyanide of potassium, according to Messrs. Morewood's patent, was entertained but abandoned as impracticable on so large a scale. The effect when properly carried out is to case harden or convert the exterior surface into steel. The patent process of Madame de Lavenant was tried with great promise of success, but with ultimate failure. Her plan is to coat or paint the iron with a preparation of finely pulverized glass, which is then submitted to such a heat as will fuse the preparation and form an enamel surface.

Ultimately the ordinary course of heating the ironwork and dipping in boiled oil was pursued, four coats of paint following. Asphalte paint for the interior surfaces, and Torbay oxide of iron paint finished with Messrs. Rose and Co.'s olive green for the exposed face.

The great desideratum of the day, no doubt, is some means of permanently protecting iron from rust; this is now said to be done by Messrs. Turner and Allen of Upper Thames Street; their process is to coat the iron with bronze or copper in such a manner as to effect perfect union between the two metals; if this union of the two metals really be as perfect as stated, no doubt it will prove a most valuable discovery. Some specimens of coating both with glass and bronze are laid on the table for the inspection of those members who do not happen to be acquainted with these processes.

The iron work of Blackfriars Bridge was tested as the work proceeded by Mr. Kirkaldy. The specified strength of iron being such as will not increase or diminish in length more than 1-625th part on application of a tensile or compressive strain of 16 tons per inch area. This specification was arrived at on the principal that good iron will bear a strain up to 16 tons per inch within the elastic limit, with a regular increase or diminution of dimension of 1-10,000 part of its length per ton per inch. It must be remembered, however, that at the time this specification was drawn the experiments on iron were by no means so full or reliable as those carried out by Mr. Kirkaldy within the last six years. The proportion of extension and compression arrived at by Mr. Hodgkinson from very few experiments was adopted too generally, regardless of the very different qualities of different makes of iron.

It is more usual to specify a breaking strain only, but iron has been permanently injured, in fact destroyed for building purposes a considerable time before it breaks under experiment. As soon as the elastic limit is passed the iron is in fact destroyed, and the element of time, and a considerable time too, must enter into the question of what really is the breaking weight. If weights be increased rapidly or at short intervals, the iron will absolutely bear considerably greater weight than would have broken it if left on for a length of time.

In fact, the following elements all bear in an important measure on the question of strength of iron—namely, elastic limit, weight ultimately borne and time of bearing beyond elastic limit, and also the diminished sectional area at the point of fracture, the contraction of area marking strongly the ductility of the material.

In Southwark Bridge the thrust on the cast iron arches is about 2¼ tons per inch, in Blackfriars wrought iron arches the thrust is 3½ tons. A somewhat slighter arch would have been perfectly safe, but it was considered that there would be more and perhaps objectionable vibration with less metal in the ribs. The cross section of Southwark Bridge arches is that of a simple flat plate with insignificant enlargement at the extremities, a form very much wanting in lateral stability, depending, in fact, for lateral rigidity entirely on the cross bracing. In wrought iron arches, on the other hand, there is great facility for placing the strength principally in the intrados and extrados of the arch, giving considerable breadth and lateral strength at those parts, thus placing the material in the most advantageous position to resist not only vertical vibration but lateral also.

The arches of Westminster Bridge are of peculiar construction: they are not what they appear to be on the external elevation, that is arches flat at the crown with sharp curvature at the haunches. The real arch terminates many feet from the apparent springing, the haunches are in fact overhanging piers, massive cast iron work standing as part of the pier corbelled over. The iron work of the arch (not the roadway) is thus made continuous throughout, the effect of which is much to increase the vibration, a vehicle on one arch thus affecting the adjoining arches. This same effect of continuous construction may be observed very strongly in the Victoria Railway Bridge, a train at one end of the bridge causes very considerable vibration at the other end. In Blackfriars Bridge, in order to avoid this effect, the iron work of each arch is made entirely distinct from the iron work of the adjoining arches. No motion can be communicated from one arch to another except through the masonry of the piers.

The granite, the bricks and the cement used in Blackfriars Bridge were also tested by Mr. Kirkaldy—and specimens are laid on the table. The granite used was from the De Lank quarries, near Bodmin, Cornwall. The following is the analysis:—

ANALYSIS OF DE LANK GRANITE.

	SPECIMEN. D. L.	AVERAGE OF GRANITES.		
		Maximum.	Minimum.	Ordinary.
Silica	68·85	76·08	66·0	72·8
Alumina	23·46	17·77	11·0	15·3
Potash	—	8·88	4·0	6·4
Soda	2·52	2·50	00	1·4
Lime	trace	1·50	0·0	0·7
Magnesia	trace	2·00	0·0	0·9
Iron Oxide	1·19	2·50	0·5	1·7
Iron Pyrites	3·18	1·50	0·0	0·0
Loss by Ignition ...	0·80	—	—	0·8
	100·00			100·00

There is little doubt that the quality of granite depends more on the amount of iron and soda contained than upon any other quality, and the suggestion is thrown out whether more attention should not be given to this point than is usually done.

Blackfriars Temporary Bridge—this bridge, though but a temporary structure did duty as one of "*The Bridges of London*" for five and a half years, and owing to the better gradient, it was found such an improvement upon the old stone bridge, that there was immediately a marked increase of traffic, it may therefore deserve a passing notice.

The London, Chatham and Dover Railway Bridge being in progress, and a much wider space being required for New Blackfriars than was occupied by the old stone bridge, there was not sufficient width between the two to build the temporary bridge, with carriage way in the middle and footpaths on each side. A two storey bridge was therefore adopted, with carriage way below of 28 feet width, the same as the old bridge, and two footpaths above of 9 feet each or 2 ft. wider than those replaced. The headway for the carriage traffic was 16 ft.

The carriage way was 53 ft. above the bed of the river, and the footpath 18 ft. above that, making a total height of 71 ft. Three openings 75 ft. each were left for the river traffic, the road over which was carried by wrought iron girders.

The carriage road was the ordinary wood pavement, which answered well with once renewing and occasional patching. It was, no doubt, slippery in certain states of the weather, and required great attention in cleansing and sanding, but, on the whole it is felt that no other road formation would have been so suitable under all the circumstances, and the experience seemed to show that the final decision to adopt wood pavement was right in this case, notwithstanding the objections to wood pavement and its admitted inferiority in permanent streets with solid foundation.

Much fear was expressed before the bridge was opened as to its safety and stability, but, on taking down, not a bolt or timber was found disturbed or fractured, and the vibration on the top, though it appeared considerable, was in fact only a quarter of an inch, and singularly enough, the greatest vibration was produced by empty four-wheel cabs.

All the ties and braces were notched on one quarter of their thickness as well as bolted; this notching injures the timber slightly, but very great rigidity is thereby obtained if well done; in fact, if the timbers be not notched into each other the mere bolting admits of very considerable lateral play.

It may occur to some that the temporary bridge might have been placed on the up-stream side of the old Blackfriars Bridge, the objections to this were the much greater length of restricted river way and the interference with property in Albion and Chatham Place.

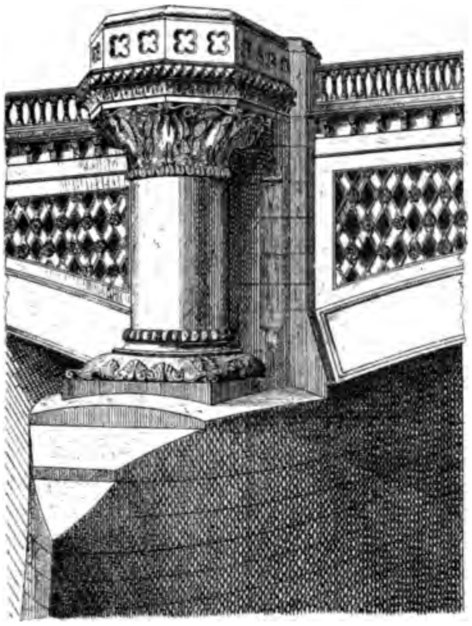
It was thought desirable to put some limit to the weights to be taken over this bridge. Notice was, therefore, put up that loads drawn by more than four horses would not be allowed to pass. The difficulty, however, was got over, by the drivers generally taking off the third pair of horses at the commencement of the bridge, and going over with the orthodox four.

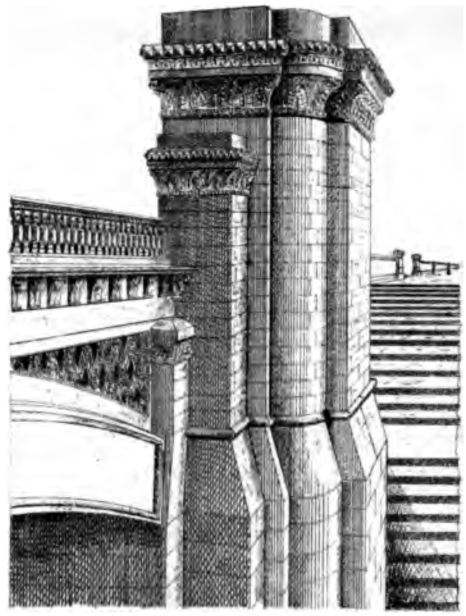
The time occupied in the erection of this temporary bridge was just over seven months.

"*The Bridges of London considered as Works of Art.*" Under this fourth head much might be said, but at present it is not for an engineer to lay down the law in a paper to be read before the Institute of Architects.

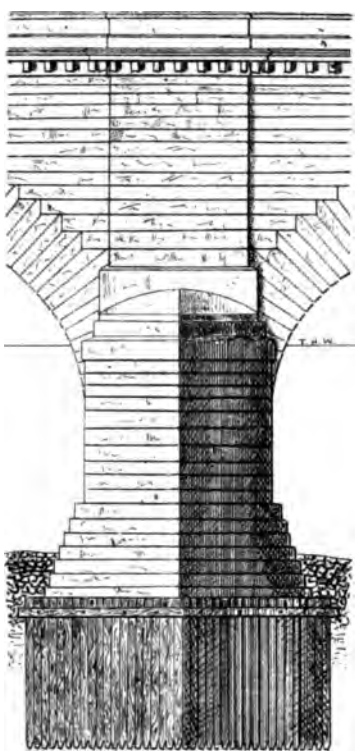
If an architect has but a barn to build at an expense of a few hundreds he proves himself a poor architect if he does not put into it some artistic feeling, be it only good proportion; it is his acknowledged duty to do his work artistically—not necessarily expensively—but to do it with some

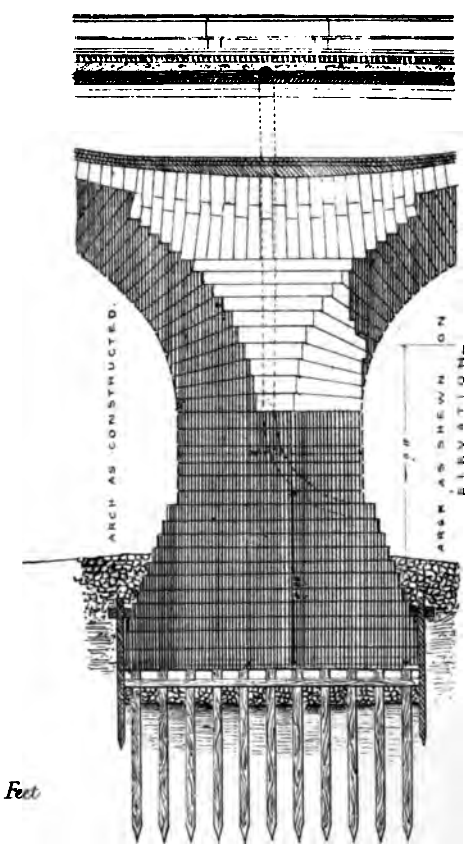
BLACKFRIARS BRIDGE.





LONDON BRIDGE.





10 0 10 20 30 40 50 60 Feet

Photo-Litho^d for the R.I.B.A. by Whiteman & Bass, London.

feeling for his art. An engineer, on the other hand, may spend millions on a railway, without having one work upon it with any real artistic feeling, either in proportion or ornament; nevertheless he may be a great and a good engineer. It has not hitherto been considered as any essential part of an engineer's duty to do *his* work artistically.

It is by no means intended to be said that *no* engineering works are artistically good, but such is far from the case generally, more frequently is not even aimed at, at all events not in the same sense or manner in which an architect's work is intended to be done. An engineer may succeed without intending it, and an architect may fail after the most strenuous efforts. For instance, Smeaton says nothing, and probably thought nothing, of beauty of outline in designing the Eddystone lighthouse, nevertheless, the outline of that tower is as beautiful a line as can well be drawn. But to return to the subject under consideration—" The Bridges of London." All that shall be attempted shall be to throw out a few suggestions for consideration. First, with regard to London Bridge, acknowledged on all hands to be one of the finest bridges in Europe, there is one point which would perhaps give an unsatisfactory feeling to an engineer rather than to an architect, namely, the concealed skewback, which leaves the arch apparently standing on a point at the springing; there is no apparent support for the arch. A bold well-developed springing or skewback gives a feeling of strength and stability, which in this bridge is left to be inferred.

One of the most important considerations in bridge building is the adoption of a style and design suitable to the locality, and perhaps this may involve more radical and important considerations than at first appears. In the case of London Bridge, you have high ground on the City side, low ground on the Southwark side. The style adopted is classic in feeling, if not absolutely and properly classic. This style involves a centre and two sides absolutely alike, or so nearly so that the difference could not be discovered. The difficulty thus arising is got over to some extent by "fudging" the parapet line somewhat, and the road still more, thus acknowledging that the design does not altogether fit the situation. By this means, however, a fall of 3 ft. 6 in. is gained in the road without visible change of external elevation, but even with this gain, the value of the bridge as an engineering work is greatly diminished by the steep approach from the south. The gradient of approach is in fact sacrificed to the uniformity of elevation. It is not implied that some other course ought certainly to have been adopted, but the difficulty is thrown out as a matter for consideration. It is in fact a case of *uniformity and dignity of design* versus *utility*. The gradient of the south approach is now 1 in 23; had the drop of the two southern arches been increased, the gradient over the whole might have been 1 in 31, a difference of vast importance to this heavy traffic.

Waterloo Bridge again is a similar case, but there the convenience of approach has been sacrificed to uniformity of elevation even to a much greater extent. This bridge must be considered not only as classic in feeling, but as an absolutely classic structure, utterly rigid and unpliable. The horizontal line is boldly carried right across the river regardless of consequences, and the southern approach is left to accommodate itself as best it can. The gradient of the southern approach is now 1 in 30, it might have been 1 in 50. London Bridge, merely classic in feeling, can accommodate itself to circumstances to some extent. Waterloo Bridge, absolutely classic, is rigid and perfectly unaccommodating.

He would have been a bold man who, in building across the Thames at London, would have placed the central point of his bridge as near to the northern shore as the navigation would permit, and then have inclined the sides in the manner most suitable to the ground; but there is a question whether a good engineer and true artist would not be able to build in the manner most suitable to the requirements of the case, and at the same time to make his work express his object with true noble and satisfactory artistic feeling.

Even the bare suggestion of a lobsided structure over the Thames is perhaps too much, nevertheless it may serve to draw attention to the difficulties in certain cases of combining architectural design, with utility in bridge building.

There is one feature in new Blackfriars Bridge which may be worth a passing notice, as it certainly is not usually adopted, and is believed to be novel. In this bridge, the springing line of arch at the piers is on a higher level than at the abutments. Had the springing line of arches been maintained at the same level throughout, the spandrils of the centre arch would have been 4 feet deeper than they actually are, involving an awkward disproportion between the small spandrils of the land arches and the large spandrils of the centre arch. This is avoided by lifting the springing of the piers, thus letting the springing line of the arches to a certain extent follow the gradient of the road. This departure from the horizontal line in the springing of the arches probably would never be noticed; it has considerable effect however in lightening the central portion and bringing it into harmony with the sides.

The lifting of the springing line, not only effects the object of giving better proportioned spandrils, but it gives increased headway for the navigation. This matter of headway became a vital question with the Bridge House Estates' Committee in determining the design to be adopted, the question of interference with the navigation finally deciding the choice of a five-arch bridge in preference to one of three arches. At first sight it may seem strange that a bridge with four piers should interfere with the navigation less than a bridge with only two piers, nevertheless that is the case in this particular instance, both as regards high and low water. In a three-arch bridge, the headway under the haunches of the large arches would be so low as to render a considerable portion of the arch unavailable, as well as the space occupied by the solid pier itself, and at low water the centre arch alone would be available for navigation; there would, it is true, be a considerable space of water under each side arch, but neither thus separated sufficient for vessels to pass. Whereas in a five-arch bridge, the higher springing line permits the whole extent of the archway to be used at high water, and at low water the whole space of three arches are available.

In these remarks it is assumed that both in three and five arch designs, the headway under the middle of the centre arch is at a fixed and previously determined level, and that a large arch necessarily has a greater versed sine than the smaller arch, involving a springing at a lower level.

This paper has already occupied too much time to allow of further remarks. Something might have been said as to the various styles adopted for the different bridges, but no information could have been given by such criticisms. Every member of this Institution can form an opinion more to the purpose than anything that might have been said here. These works are before us all: they are not in a far distant country which only few have the opportunity of visiting.

APPENDIX.

A variety of experiments on the strength of materials were made by Mr. Kirkaldy for the works of the new bridge at Blackfriars, some of which gave results as follows:—

BRICKS, IN PIERS FOUR COURSES HIGH.

Description of bricks.	Size of pier in bricks.	Mortar.	Failing slightly. Tons per foot super.	Entirely crushed. Tons per foot super.
Common stock recessed ...	$1\frac{1}{2} \times 1\frac{1}{2}$	Lias lime	17	27
Ditto ditto ...	$1\frac{1}{2} \times 1\frac{1}{2}$	Ditto	21	30
Red bricks, machine-made ...	$1\frac{1}{2} \times 1\frac{1}{2}$	Ditto	20	40
Ditto hand-made ...	$1\frac{1}{2} \times 1\frac{1}{2}$	Ditto	20	36
Galt	$1\frac{1}{2} \times 1\frac{1}{2}$	Roman cement	24	59
Ditto	1×1	Ditto	54	72
Clark's Sudbury machine ...	1×1	Portland	49	76
Uxbridge red, hand-made ...	1×1	Ditto	44	53

STONE CUBES OF TWO INCHES BEDDED ON SHEET LEAD.

Description.	Failing slightly. Tons per foot super.	Entirely crushed. Tons per foot super.
De Lank granite, Cornish ...	283	363
Ditto	279	—
Ditto	349	377
Guernsey	276	830
Ditto	761	1150
Cheesewring, Cornish ...	295	403
Ditto	194	322
Portland	106	155

A small polished column of red Mull granite, length, 6 ins., diameter, nearly 3 ins. was cut through the middle, and the cut faces accurately ground, when tested, packings of pine were placed at each end and the surfaces where cut in two, were put together with a little boiled oil. This 3-in. column

bore a strain of 60 tons, or $8\frac{3}{4}$ tons per square in., 1260 tons per square ft., or the weight of a column 16,380 ft. high.

An experiment was made to test the effect of a small area of iron pressing on a surface of De Lank granite. A cube of 1 in. wrought iron was placed between two blocks of granite, 6 in. by 6 in by 5 in. a packing of $\frac{1}{4}$ in. of pine was placed between the granite and the machine, and between the iron cube and granite. One of the blocks was split with a pressure of 50 tons, the block which was not injured was again submitted to pressure with another cube, it was then fractured with a pressure of 52 tons. The iron cubes were reduced in thickness one-sixth. with an equivalent lateral extension.

It was desired to see what would be the effect of great pressure on the skewback stones. A stone was worked 1-4th scale and a corresponding portion of arch rib made, the two were bedded together with lead run in between, in the same manner as proposed for the arches themselves. They were then gradually submitted to a pressure of 200 tons, but without any effect except extrusion of the lead, the iron, however, with 18 tons per inch seemed to have quite as much as it could carry. Being all to 1-4th scale, the area under pressure was 1-16th the real size, the pressure was therefore equivalent to 3200 tons in the bridge itself, the actual pressure in work being under 400 tons.

Gun metal cramps were also tested, the result being the rejection of several mixtures of metal submitted by the contractors, and an increase of strength obtained from 17,519 lbs. per inch area to 28,883 lbs ($7\frac{3}{4}$ to nearly 13 tons.)

In order to test the strength of timber used as struts, two whole balks, 20 ft. in length and 13 ins. square, were submitted to end compression. The red timber crippled with 138 tons, or 112 tons per foot area, and the white with 147 tons, or 126 tons per foot area, the reduction in length being in one case $\frac{5}{8}$, in the other $\frac{1}{2}$ in. Specimens of the fractures are now exhibited.

Portland cement was also tested, the standard of the Metropolitan Board of Works being adopted, 110 lbs. weight per bushel, and 500 tensile power on $2\frac{1}{4}$ ins. area; some results obtained were as high as 733 lbs. on the $2\frac{1}{4}$ ins.

Experiments were made on the iron from time to time, but the specified strength was not fully attained, it was perhaps pitched rather too high for such work. The extension of $\frac{1}{833}$ part of the length was given by strains varying from 13 to 15 tons instead of 16 tons, but even with this, the elastic limit is just about four times the working load, which is ample allowance for safety, taking into account a very large deterioration from time and corrosion.

The above figures are stated in round numbers. The results as given by Mr. Kirkaldy, are in every respect most accurate and minute, but high numbers of pounds instead of tons, and long decimals are not suitable for such a sketch as this.

The CHAIRMAN: I now have the pleasure of calling upon gentlemen for any observations they may have to make upon Mr. Carr's very able and excellent paper.

MR. AITCHISON (Fellow): I really am quite unprepared to make any remarks upon the very interesting paper we have just heard read; and it is needless for me to say how exceedingly obliged to Mr. Carr we are for giving us such valuable materials—materials which I do not know where we could get elsewhere. One of the most useful things, both for architects and engineers, is to know the exact weight that has been put upon the foundations of large and heavy structures; and that information I have found to be most difficult of attainment even with the most patient inquiry. Many of the data now given by Mr. Carr, when found, after being hunted up in books and reports, do not by any means give us the same valuable results as when put before us by a gentleman of Mr. Carr's ability and experience. It appeared to me that 88 tons was an almost incredible weight to put upon each of

the piles of London Bridge, when I found that stated in the report, more especially as from 20 to 40 tons is considered a heavy load, but I think from Mr. Carr's statement that some portion of the 88 tons must be carried by the intervening space filled in, as he tells us, with rubble and brickwork, and therefore the load really borne by the piles is an unknown quantity, and even then, in the instance he shows us, the weight has had the effect of splitting the pile right down. Mr. Carr has suggested that it would have been much better to have placed this weight evenly over the whole surface, and no doubt that would be the case. I think I may draw the attention of the members of this Institute to a small pamphlet published by our late respected Fellow, Mr. Savage, when engaged in the controversy on London Bridge, who pointed out that the effect of driving the piles into the clay was to raise the clay into the condition of puff paste; that is to say, the continual vibration caused by driving the piles, split the clay into horizontal laminæ. At that time, however, it was thought best to trust to the hard piling than to a surface of clay. There are very many other interesting points connected with this question, such as the weights put upon the clay, by Mr. Hawkshaw in his railway bridges at Charing Cross and Cannon Street. I understood him to say that he had as much as 8 tons per square foot on the London clay at the Cannon Street Bridge, and although I understood that some of the cylinders sunk four inches, he told me that there had been no observable settlement since the completion of the works. While I am touching upon the subject of cylinders, I may say that there has been a very curious and ingenious invention made by an engineer in the North, Mr. Millroy, during the last few years, and which has been used on a wharf on the Thames, just below the Hermitage entrance to the London Docks. Mr. Kendell was called in to design this foundation, and he proposed to carry it down into the London clay on cast iron cylinders, the sinking of which, however, would have been very expensive, as it had to be done by divers, or by the compressed air process; but by using the machine a great saving was effected. The machine consists of a circular ring of iron, on the bottom edge or surface, of which there are hinged teeth or spades. The ring or cylinder of iron was jumped down inside the cylinder on to the ballast, by means of chains; these chains were then slackened, and another set brought into play which were attached to the hinged spades and passed through a central ring, closing the whole into a shape like the top of a fig drum, and bringing up a certain quantity of gravel. As the gravel was got out the congested cylinders sank. After the machine had worked itself to a sufficient depth in the clay, the interior of the cylinder was pumped dry, and the laying of the foundations commenced.

As far as the question of wrought or cast iron for bridges is concerned, there is no doubt that wrought iron is in many respects a more convenient material. Apparently, as the world gets older people seem inclined to make their structures of more flimsy material; perhaps it may be because in every respect, save utility, they are of such little value. Wrought iron, as long as it is attended to by the hand of man, will perhaps last as long as any other material; but leave it to the operation of the weather, what is the effect? What would be the result upon the many wrought iron bridges of the kingdom in the event of the suspension, from any cause, of the general activity of England? Suppose the Menai Bridge or the Britannia Tube were to be left to itself for ten or fifteen years and nothing to be done to it? The probability is that it would tumble into the Straits of Menai beneath. I do not think we can look upon wrought iron, where it is exposed to the weather, as a material that is very consonant with a building of at all a permanent or rather of a monumental character. Cast iron, although it has many defects, has also those advantages which Mr. Carr pointed out, for being of considerably greater thickness, and less liable to oxidation than wrought iron, it is less injured by neglect of painting. We have never seen any very fine bridge, as far as I am aware, constructed of

wrought iron, but I suppose that is not the fault of the material. I think the finest bridge I have ever seen is Southwark. At present it is obscured by the hideous railway bridge at the Cannon Street Station, and I certainly think that no greater loss could be inflicted on London than altering the Southwark bridge so long as it will stand as it is. Of course it would be desirable to have the level of the roadway lowered, but I think it would be a great pity to destroy the most beautiful bridge we have for the purpose of slightly relieving the traffic. I am not at all certain that an increased traffic might not be accommodated on London Bridge, without spoiling it at all, by the judicious use of ironwork. It seems to me that an open arcading of iron columns, if properly designed, so as to take the foot passenger traffic at a sufficient height above the roadway, would not deteriorate its appearance, and might even add to the beauty of the bridge. The only doubt I have had on the subject is whether the present foundations can be made to bear such an additional load; but I think that if the present granite paving were taken up and asphalte laid down, possibly some saving in weight might be effected.

If the process of coating iron with copper can be successfully carried out on a large scale it will be one of the greatest boons of our time. The question is, can it be made to cover the surface completely so as to prevent the atmosphere from affecting it; if not, the galvanic action would have a most injurious effect. I do not think I have anything more to say upon the constructional part of Mr. Carr's paper, but I should like to say a few words on the artistic part. It is quite true, and it is the misfortune of the present day, that there is very little taste or real artistic feeling in the country. I do not know that anything can show this more completely than the fact that the greater number of buildings now erected, at an enormous cost,—purely architectural work be it remembered,—have a front only; the front is elaborated and decorated at an enormous cost; and why is this? The front of the building, if sumptuous, answers as a good advertisement; but look at the back and the flank walls; they are left in the commonest and plainest brickwork, without any attempt even at proportion, to say nothing of ornamentation. So long as the general feeling of the people is not to value art for art's sake, but for some subsidiary purpose, we can hardly expect that they will insist on structures of a purely utilitarian character being made beautiful, even when enormous sums of money are expended on their construction, and consequently we cannot expect engineers to devote some of their time to artistic study when the greatest proficiency attained would add nothing to their pecuniary advantage, and probably very little to their reputation. But I cannot see why, if we could induce a love of art amongst the people, the engineers should not devote a small portion of their time to the general study of æsthetics. I have not the slightest doubt that if they would take that trouble we should have quite a new style, and of a character superior to anything that has been done before in England. It is by no means intended to be said that no works of engineers are artistic; as I said before, Southwark Bridge is one of the most beautiful bridges that has been erected, and next to that I think that the very finest thing that has been erected in my time, is the Cannon Street station; the effect of the inside of that building is, to my thinking, very nearly perfect. I do not suppose that it was arrived at by any intentional striving after artistic effect, but was brought about, I imagine, by the lines of force and beauty accidentally coinciding. It is undoubtedly the case that in most structures, whether they may be called Classic or Gothic, the true artistic feeling, which is the only thing that is valuable to be cultivated by the architect or engineer, is lost sight of. The people who did these things in times gone by had a certain amount of artistic feeling, and they used then to execute their works in the best way they could; but we generally attempt to make servile imitations or servile paraphrases of the artistic works of other times. If it were not so, we should see the thoughtful spirit which animated those people animating the

builders of the present day. As far as bridges go I have not the slightest doubt that what Mr. Carr has said is perfectly true. Though I have no practical knowledge of bridge building, it seems to me that the deepest part of the river is by no means in the middle; and it would strike any ordinary person who was building, that where the deepest water is, there he would require the highest arch, and so far from that producing an ugly structure, any person who has passed along the railroad and seen the bridge at Berwick, where the highest point is one-third from the shore, will be ready to say that there could not well be a more picturesque structure. I do not know that I have anything more to say except to express my great thanks to Mr. Carr for his interesting and valuable paper.

Mr. SEDDON (Fellow): I will not detain you long at this late hour of the evening, but I should like to make one remark upon the last section of Mr. Carr's paper, upon which Mr. Aitchison has also just touched. There are many lob-sided bridges of mediæval date still remaining: not so many as could be wished, however. Here is the drawing of a small bridge over the Taff, at Landaff, which presents all the peculiarities which Mr. Carr and Mr. Aitchison desiderate; and here is the drawing of another over the Ely in the same neighbourhood. I sent down and had the drawings made on purpose for this occasion. These bridges are examples of how our forefathers solved a difficulty when they had one to contend with, and while accommodating them to the currents of the rivers and the different levels of the opposite banks, they continued to render them picturesque and artistic. In passing, I should like to express my admiration at the way in which Mr. Carr has attempted to meet the same ends, and also many other excellent points, in the New Blackfriars Bridge. I am most happy to second the vote of thanks to Mr. Carr for his paper, which he readily consented to prepare at the instance of the Council (conveyed through me). He has dwelt upon the general character of the bridges of London rather than upon any one in particular, in deference to the request made to him; but I think that if we might, at some future time, have from Mr. Carr some more minute description of the great bridges with which he has himself been connected we should be exceedingly grateful, and thoroughly appreciate what he might lay before us.

MR. ARTHUR CATES (Associate): I wish to say a few words as to the proposed alteration of London Bridge. It seems to me exceedingly undesirable that it should be thought that this Institute approves the suggestion that additional footways should be placed (carried on iron columns) above that bridge. I individually beg to offer my protest against it, and to observe that the method devised by Mr. Carr for gaining an increased width of footway, appears to me to be a very feasible and unobjectional method of increasing the accommodation in that portion of the bridge where accommodation is most required. As regards Southwark Bridge, there is no doubt that its mass, its proportions, and general appearance command respect; and it is exceedingly to be regretted, that it is not fitted to accommodate a larger amount of traffic than it does. If the cast-iron arches were replaced by arches of wrought iron, as proposed, we have not sufficient information before us to know what the effect would be, and therefore cannot well form an opinion. It appears to me that the great objection to the more general use of Southwark Bridge arises more from the nature of its approaches than from the gradients of the bridge itself. The approaches, especially that in Queen Street Place, afford greater difficulties than are presented by the bridge itself; and it would be a subject of serious consideration whether the remedies deemed expedient by Mr. Carr would produce a result commensurate with the great cost to be incurred in the re-construction of the superstructure of the bridge. In speaking of the foundations of the bridge at Westminster, Mr. Carr did not notice one feature in the construction of that bridge, whereby there was no necessity for the construction of a temporary bridge, such as was used at Blackfriars. Mr. Page, the engineer of the New Westminster Bridge, obviated the necessity of making a temporary bridge, by using the old bridge for the traffic until one half (laterally) of the new bridge was completed; when the traffic

was diverted from the old bridge to the finished half of the new bridge, the old bridge removed, and the remaining half of the new bridge completed. That method of construction may account, in some manner, for the peculiarity of the foundations, where the piles are used in a manner to which I understand Mr. Carr has made some objection. It would appear, undoubtedly, that both in London Bridge and Westminster Bridge, it would have been desirable to confine the solid foundation of the piers to the clay itself, without breaking up the body of the clay by driving piles. It would have been very satisfactory to all of us if Mr. Carr had entered more fully into the details of the great work on which he has himself been engaged, and I am sure that though addressed to a body of architects, further details of that great structure would be most acceptable. There are many points on which we may be desirous of information, and for one I may mention the reasons which have guided the designer of that bridge in giving their particular forms to the upper parts of the cut-waters or starlings, and also as to the reason why on a bridge of that character, recesses were adopted. Now on reformed old London Bridge and also on Old Westminster Bridge there were recesses and alcoves. On the New Blackfriars' Bridge there are recesses but no alcoves. The new Westminster Bridge has a straight parapet and no recesses. It appears to me that these recesses serve no useful purpose whatever; on the contrary, they are used for exceedingly unpleasant purposes. Mr. Carr has placed upon the table a specimen showing the fracture of a rolled iron joist. We have had no account of it, and I for one shall be glad to hear something about it, as it is very desirable indeed to have some record of such experiments. I regret exceedingly that with the able paper we have heard, we have not had more detail of this kind, and I am sure that if Mr. Carr, at some future period, will be able to favour us with an account of the work in the new Blackfriars' Bridge, and the experiments connected therewith, it will be received very cordially by us. I have great pleasure in supporting the vote of thanks to Mr. Carr.

The CHAIRMAN: Gentlemen, I need not ask you formally to assent to this vote of thanks to Mr. Carr for his valuable paper read before us this evening, but will at once call upon Mr. Carr to reply to what has been said in the discussion.

MR. CARR: I will endeavour to reply to the remarks of the previous speakers in the order in which the various subjects have been mentioned by them. First of all with regard to the foundations of London Bridge. The failure of the timber experimented upon is in the sills. Even supposing that the piles stood perfectly firm, it would not be safe to put more than twelve or fifteen tons, at the very outside, on the sills in that position; but there is not the least doubt that as the interstices are filled in between the piles and the sills, the weight presses upon the whole area of the pier. With regard to the rusting of iron, the great objection to wrought iron is that it is used in thinner plates than cast, and has a greater liability to rust; but if looked at from time to time, and carefully attended to, it will last well. Cast iron is not so liable to rust. Southwark Bridge, which is of cast iron, has not been painted, I believe, for the last fifteen years, and is in a very good state of preservation even now. As concerns the coating of iron with bronze, it seems to me that if what has been represented is true, it is a most valuable invention. It is a new process, not that lately tried in Paris. The process of coating iron with glass I paid a great deal of attention to in the first instance. We had a portion of the parapet of the new Blackfriars Bridge coated with it, and it stood upon the works for two years, but I am sorry to say it did not succeed. The specimens upon the table look very well to the naked eye, but if you examine them with a microscope, you will see that there are numerous air-bubbles in the enamel covering. The great desideratum in anything for coating iron appears to me to be to get perfect contact, perfect union between the iron and the material with which it is covered. If you have the

slightest portion of oxide remaining between the two, oxidation will go on, and the covering will in the end peal off, leaving the iron exposed. As regards Southwark Bridge, the necessity of interfering with its noble arches is to be regretted; but it is a question of preserving it as it is, *or of rendering it a work of real utility*. There is no doubt a difficulty with regard to the approaches, especially as regards Thames Street. It had been proposed to cross this thoroughfare by a bridge over the street; this, however, involves a great number of additional considerations. With regard to lob-sided bridges, I should have no objection myself to have a lob-sided bridge on the Thames, though the Thames is hardly to be compared with the Taff. With regard to a temporary bridge being required at Blackfriars and not at Westminster, during the rebuilding of the permanent bridges at those spots, it is very questionable whether there is any economy in dispensing with a temporary bridge. Supposing the foundations in both cases to be of the same character as regards expense, it is very questionable whether, instead of dividing the bridge into two distinct works and increasing the duration of your contracts, it would not be better to spend £30,000. and build a temporary bridge as was done at Blackfriars; but it is a question for consideration under each particular case. At Blackfriars a temporary bridge could not have heen dispensed with, as the centre line of the new coincided with the centre line of the old bridge, whereas in the case of Westminster the whole increase or half the new bridge was to one side. Then with regard to the shape of the upper part of the cut-waters of the new Blackfriars Bridge, I cannot give you any particular reason for their adoption. We engineers do not pretend to deal with all these matters of taste as architects would do; if it is thought an ugly shape, I am sorry for it, but it is the best we could devise. As to recesses, I think they serve to break up the line of the parapet; I certainly do not like the straight unbroken line of Westminster Bridge. But after all, this is very much a matter of taste. With regard to the specimen rolled joist, it is unconnected with the bridge; but Mr. Kirkaldy very kindly furnished several matters connected with the testing of materials, and along with other specimens he sent that piece of rolled joist, which merely illustrates an experiment carried on at his works. The bridges of London include a very large question, and I think myself that if the paper had comprised but one tenth of the subject matter, and that tenth had been dwelt on more fully, it might have been made more interesting and more useful. I, however, adhered to the text given me, "The Bridges of London." There are a great many subjects touched upon in the paper, and only just touched upon, for one cannot go fully into all these matters in such a limited time. If anyone will follow up the text I have given, there is a great deal of matter in connection with the bridges of London that might be made of great interest.

The CHAIRMAN: I will not detain the meeting long. The subject, as you say, Mr. Carr, is one which is important, and upon which there is great room for observation; but you have modestly refrained from mentioning any detail of your own great work; and I am in hopes that, no one being so fit as yourself to enlarge upon that subject, you will give us further details of it at some future time. There is no doubt, as Mr. Aitchinson has said, that your paper is an exceedingly valuable one, and I may say that its value is increased by its appendix. I have myself lived to see every bridge in London built, and almost my first professional work was in connection with London Bridge. I have seen the bottom of its foundations, and I recollect perfectly well the old structure with its starlings, which preceded it. I have still to ask you to have the kindness to consider whether you will take up another tithe of the subject you have so ably treated to-night, and give us some details of your own great work.

Mr. CARR: Shall I be out of order in challenging some architect to give us a paper at the Institution of Civil Engineers?

The CHAIRMAN: Your challenge has been boldly given, and I hope it will be promptly responded to.

Mr. PHENÉ SPIERS, Associate: Might we be so fortunate as to hope that Mr. Kirkaldy will some day be asked to give us a *resumé* of the vast number of interesting experiments on building materials that he has conducted for so many years past? With several members of the Architectural Association I have been over his works, and I am sure that a paper from him would be full of interest.

Professor KERR, Fellow: Mr. Seddon's brother, Captain Seddon, of the Royal Engineers, is to read us a paper "On the necessity and method of testing of building materials;" and perhaps Mr. Kirkaldy would be kind enough to attend on that occasion and provide himself with some useful data.

The Chairman then announced that the meeting was at an end.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 18th December, 1871, the following Paper was read, EDWARD I'ANSON, Vice-President, in the Chair:—

A BIOGRAPHICAL NOTICE OF THE LATE SIR JAMES PENNETHORNE.

By ARTHUR CATES, Associate.

FROM time to time, as death removes from among us our most esteemed and valued members, it becomes a duty and a privilege to place on our transactions some record of their career; and brilliant as has been the success of many of those of whom memoirs are already inscribed on those pages, there is not one who had more disinterestedly, thoroughly, and earnestly, devoted his entire life to the conscientious discharge of the responsible duties imposed on him—or one more worthy of our esteem and respect in both his professional and personal relations—than the late Sir James Pennethorne, whose sudden death, on the 1st of September last, has been so deeply regretted. An architect devoted to his art—the earlier portion of his official life was almost exclusively absorbed in the performance of duties for which his skill in contrivance, and his business habits and energy well fitted him, but which afforded few opportunities for the development of his architectural skill, and when the opportunities came, they were too often tramelled with conditions which were very prejudicial to art. Yet from the nature of the official position which for more than thirty years he so honorably filled, any memoir of Sir James Pennethorne, which would pretend to do justice to his labours, would in fact be a history of almost all that has been done or projected for the improvement of the metropolis within that period, and of most of the great public works therein undertaken or projected by the Government; and would comprise a statement of grand projects, once quite possible, brought almost to the point of realization, and then dropped and neglected as of no importance, till at last they became impracticable: to enter into such detail would be far beyond the limits of this paper, and it will be in my power only to touch briefly on some leading points of his life and works.

Born at Worcester, in June, 1801, Mr. Pennethorne came to London in 1820, and entered the office of Mr. John Nash, under whose care, and that of Mr. Augustus Pugin, he received his professional education. A sojourn in Rome was then an essential feature in an architect's course of study; and accordingly, on October 23rd, 1824, he left London for his foreign travel. In Paris he at once made arrangements to prosecute his journey to Rome, and bargained with a *voiturier* to convey him and others to that city in thirty days, and to find them with food and lodging by the way for 600 francs each, then equal to about £24. sterling. Leaving Paris on November 6th, they arrived at Bologna on November 30th, and reached Rome on December 10th; delays and stoppages on the route in relation to passports and custom-house regulations having extended the journey to thirty-five days, and increased the cost to nearly 800 francs. The course of study he followed being somewhat different from that of most architects may be noted in his own words, quoting a letter to Mr. Nash. "The first thing we do is to make a picturesque sketch of the building, shewing exactly its present state and situation with regard to the other buildings, neatly finished in colours, on the spot, which we find the best and quickest way; and while

doing this we have time to consider and examine the general mass and proportion; these sketches are about 9 inches by 15 inches. . . . . This is the first and easiest part; and the next step is to make a drawing of the remains in plain outline, to a very large scale (on the spot), shaded very slightly, but very boldly in indian ink, to get exactly by eye the details, proportions and bas-reliefs with all the ornaments. At the same time we shall, if it is possible to get permission, take only the general proportions in measurement, to impress them on our minds. And after this we shall always, as far as we can, make a restoration of the building. Our studies being, as we imagine, divided into two classes, the ornaments and details, and the general ideas and proportions of the buildings, as also their plans and all the peculiarities connected with them, and this part requires a great deal of knowledge and reading, and can at best be but uncertain; nevertheless, it must be excellent practice to endeavour to follow the ancients through the whole of their designs, and without doing this it is impossible to have any idea of their grand conceptions, or indeed of the mathematical correctness of all their proportions, even to the slightest detail." His studies of modern Italian architecture were conducted with similar care; and he also found great advantage to accrue from drawing from the life at the Academy, and from the sculpture in the Museums. His attention was specially devoted to a restoration of the Forum, and his large drawing of this subject was exhibited a few years ago. The numerous and excellent drawings which he periodically transmitted to Mr. Nash, and the details comprised in the critical letters which accompanied them, amply testify to his industry and ability. In the autumn of 1825, Sienna, Florence, Genoa, Milan, Venice, &c., were visited; and Rome being again left on June 1, 1826, he went on to Naples and Sicily, and returned to England at the end of the same year, when he took a leading position in the office of Mr. Nash, and as his principal assistant conducted the execution of the Strand Improvements, Carlton House Terrace, St. James's Park, and other similar works.

In 1832, he was, in consequence of the experience gained by his connection with Mr. Nash, employed by the Commissioners of Woods, and commenced to devote his attention to devising plans for the improvement of the metropolis. The great works which had been carried out under the inspiration of Mr. Nash, and by which the West end of London had been in fact created, were completed. The source from which the funds, lavishly but wisely expended, had been derived, was no longer available; and a Select Committee of the House of Commons having, in 1838, approved and recommended for adoption the plans submitted by Mr. Pennethorne for Metropolitan Improvements, he was (with Mr. Chawner) appointed to carry them out, not, however, as designed by him, but trimmed and pared down to satisfy the requirements of economy; and although the four streets authorized by the Act 3 and 4 Vict. cap. 87, viz.: New Oxford Street, Endell Street, New Coventry Street, and Commercial Street, Spitalfields, have proved of the utmost service to the circulation of the traffic of the metropolis, it is now certain that could his enlightened views have prevailed over the narrow spirit which influenced the decision on his plans, the metropolis would not only have been greatly benefited, but improvements greatly needed, and now rendered almost impracticable, would have been carried out at moderate cost. It is not necessary here to enter into detail with regard to these improvements; much information with regard to them will be found in a paper read before this Institute by Mr. Thomas Miller Rickman, on February 21, 1859, on Metropolitan Improvements, &c., and in two articles in the *Mechanics' Magazine*, of October 7 and 14 last, entitled "Pennethorne and Public Improvements," which I may attribute to the well-known hand of Mr. Edward Hall; but it is important that, Mr. Pennethorne having acted as the executive officer of the Royal Commissioners for Improving the Metropolis, any responsibility for those imperfections in the works carried out, against which he constantly protested, should not be thrown on him. Until the formation of the Metropolitan Board of

Works (1855) he was constantly engaged in devising schemes for improvements, which were more or less advanced, some even having been brought before Parliament; but all general projects fell through from the difficulty of providing the necessary funds, a difficulty which is now removed. Besides the formation of the new streets, and other improvements, such as those at Pimlico, Kensington Palace Gardens, Windsor High Street, &c., he carried out Victoria Park, Kennington Park, and Battersea Park; the works of the latter, after many years of delay, having been hurried on in a manner which prevented the complete realization of his design. The scheme for a Northern Park, which in 1852 was proposed to be formed under the name of Albert Park, was fully worked out by him; and had funds been available, and the project realized, would have added largely to his reputation as a landscape gardener.

Devoted as he would thus appear to have been to the one great subject—the improvement of the metropolis—and to advising successive administrations with respect to the great schemes each brought forward, only to be dropped under pressure of political exigencies or otherwise, he was only on one occasion called away therefrom, when, in 1843, he visited Ireland as Royal Commissioner to enquire into the construction of Workhouses. Previous to 1840, when his entire services were required by the Government, he had carried on a considerable practice as an architect—a list of these buildings will be found in the Appendix to the Sessional Papers, 1856-57, and his design submitted in competition for the Royal Exchange was one of the five selected—but until 1845 no worthy opportunity was afforded him of applying his architectural ability to the public service. It then being determined to erect a Museum of Economic Geology, on a site between Jermyn Street and Piccadilly, the preparation of the designs was placed in his hands, and, after having undergone the usual course of emendation and reconsideration, to please the varying tastes and fancies of succeeding First Commissioners of Works, the building was erected, and deservedly takes a high position among the edifices of the metropolis—whether from the dignity of the well studied elevations, the picturesque effects obtained in the interior, or the remarkably commodious arrangements by which so much accommodation is so well provided on a limited site. The lecture theatre and the museum are each admirably successful, and as his first public work, it is worthy of commendation equal, at the least, to that so deservedly bestowed on his latest work, the University of London. The success of this building speedily brought to him further employment, and he was soon engaged on designs for a Public Record Office, with reference to which a slight digression may be allowed.

The history of almost every public work on which Mr. Pennethorne was engaged would illustrate the long period of incubation which in this country intervenes between the acknowledgment of the necessity or desirability of an undertaking and its realization, after many years of vacillation and delay. As to the obligation which falls on us to maintain intact, and hand down to our successors, the invaluable records of the realm, which, whether from a legal or a literary point of view, are priceless, there can be but one opinion: and it would be thought that so soon as the necessity for a safe and secure depository for such documents had been recognized, active means would have been taken to provide it.

In the 19th and 20th Edward I, A.D. 1291, the records of the Court of Chancery were deposited in the King's Treasury, in the New Temple, in a chest secured by nine keys. These records were at a period not ascertained, removed to the Tower of London, where, in 1305, other records were deposited, and from that period the King's Treasury in the Tower was the Public Record Office; and till a few years back, the upper stories of the White Tower were so used, the basement being appropriated as a magazine for gunpowder, and the intervening floors as warehouses for ordnance stores, tarpaulings, and such like things, where lights were freely used. At the Rolls House and Rolls Chapel in Chancery

Lane, was another depository of these valuable documents, many of them being kept in the chapel where divine service was performed weekly, being there deposited in the seats of the pews, behind the altar, along the walls, and in the roof. The Chapter House, Westminster Abbey, having been previously used for the purposes of the House of Commons, was, about the reign of Edward VI., also converted into a public record office. A portion of the King's Mews (Trafalgar Square), and cellars under Somerset House, were also depositories, and when these were vacated, the Riding School attached to Carlton House was appropriated as a depository. The State Paper Office—erected from the design of Sir John Soane, in Duke Street, Westminster, must not be forgotten: this elegant structure has been swept away for the New Public Offices, and its contents transferred to the General Record Office.

The idea of a General Repository appears to have been suggested in 1647, when a Committee of Parliament was appointed to make a collection of all the papers that concern the public, "*and to reduce* " *them into one place to be safely preserved.*" In 1732 a similar idea was promulgated by the Committee of the House of Commons on the Cottonian Library. In 1823 the Chancellor of the Exchequer, the Right Hon. N. Vansittart, visited the Tower to consider some proposed additions to the Record Office there, and as a result of that inspection placed on record his opinion that "a proper building ought to " be immediately erected in some more accessible part of the metropolis, capable of uniting and con-" taining all the national records;" and this idea appears to have gained strength in the official mind, so that in 1832 a proposal was printed for the erection of a General Record Office and other buildings on the Rolls estate; and in 1834 Lord Duncannon, as Commissioner of His Majesty's Woods, gave notice of a motion for leave to bring in a Bill to empower the Commissioners to erect such buildings, but the motion was not made.

In 1836 a Select Committee of the House of Commons recommended the erection of a General Repository. In 1837 the Commissioner of Public Records, in their General Report to the King, urged the propriety of erecting such a repository. In the same year a Bill to effect that object was introduced into the House of Commons, but was dropped. At last on the 14th August, 1838, the Public Record Act, " An Act for keeping safely the Public Records," was passed, and empowered the Treasury to provide a suitable and proper building; and on the 7th of January, 1839, Lord Langdale (Master of the Rolls) submitted to the Secretary of State his view of the management of the Records, and the necessity of providing a Public Record Office, and suggested the Rolls estate as a proper site. From this point it might have been reasonably expected that the progress in providing this building—the necessity of which had for 200 years been so patent, would have been great; and, in fact, the Treasury minute of 8th April, 1839, expressed that their Lordships entirely concurred, that one general Record Office, under efficient management and responsibility, was essential; *but* signified " that it had been determined by Parliament that the Victoria Tower should be erected, and if that building could be safely adapted to the safe custody of the Records, the expense to the public of a second building would be altogether avoided; and on these grounds their Lordships were unwilling, without a more accurate knowledge of the facts and more precise information before them, to determine in favour of building a new Record Office on the Rolls estate." The Commissioners of Woods and Forests were instructed to inquire into the subject: a further proposal was made to appropriate the space in the roofs of the Houses of Parliament for the purpose; and the decision that these proposals were unfit was not arrived at till 1845.

Mr. Pennethorne having then for some years been engaged as adviser of the Commissioners for Metropolitan Improvements, on May 13, 1847, submitted to them a plan for providing an improved communication between the east and west portions of London, the plan having been made by him in 1834, and laid before the Select Committee of the House of Commons in 1838, and of that street the

only portion now formed is Coventry Street, from Piccadilly to the west end of Long Acre; of this great central thoroughfare a portion would have passed through the Rolls estate, connecting Chancery Lane at Carey Street with Fetter Lane; and at the same time Mr. Pennethorne submitted a project for erecting on the south side of the new street a General Record Repository of a comprehensive nature, carefully elaborated, and combining all the essentials for such an establishment; and the original sketch, dated January 9, 1847, is now preserved in that office, and respecting which Mr. Pennethorne in 1863, writing to Mr. Hardy, the deputy-keeper, says, "You will see that in those days we foresaw "the necessity for a large library, for large searching rooms, for the maintenance of the Rolls chapel, "and of the Court, of a house for the Master, for the deputy-keeper, &c. &c.; all these things were "washed away by economy, and will hereafter have to be provided at greater cost and with less con-"venience."

In 1850 Mr. Pennethorne's design for a much smaller establishment than that contemplated in 1847, and in accordance with which the fragment of the building now executed has been erected, was laid before the House of Commons, a vote of £30,000. on account was granted; and the works of the first portion soon commenced, the first stone having been laid May 24, 1851; in 1863 a further portion, part of the east wing, was undertaken, in which provision was made for legal and literary search rooms, the necessity for which was then apparent: in 1865 the upper story of the Central Tower was undertaken, not the grand and lofty feature which Mr. Pennethorne's design had contemplated, but just so much as would provide certain accommodation urgently required. In 1868 the contract for completing the east wing was let, and in the spring of this year Sir James was engaged in completing his designs for the west wing, which would occupy a large site extending to Chancery Lane.

The design of the elevation of this building has been dependent entirely on the exigencies of plan and construction, the deep buttresses boldly over-arched, the clear vertical lines of the piers, and the general scale are of a decidedly marked character, well suited to its destination; the internal arrangement is simple, a central corridor, and on each side depositories, each 25 feet long, 17 feet wide, and 15 feet 9 inches high, divided into two heights by a light iron gallery, and fitted up with presses and racks, constructed of light wrought iron, with shelves of slate or other incombustible material. When the design was under consideration great attention was given to the best method of construction to be adopted to secure a practically fire-proof edifice, it was generally admitted that the only really fire-proof building would be one built with brick, and vaulted in the same material, neither stone nor iron entering into its structure, but as the limits of space and economy would not permit this to be carried out, it was desired to approach as closely as possible to perfect security, by limiting the dimensions of each depository to those above-mentioned, by forming the floor with brick arches of short span carried on cast iron girders, and by entirely excluding all combustible materials from the building: as for the records themselves, it is notoriously difficult to burn paper closely packed, and it was considered that the subdivision of the bulk would tend materially to reduce any possible danger. But it is not only against danger from fire arising from within that in such a case it is necessary to provide, there is the, perhaps, greater risk of fire communicated from contiguous buildings, and the plans of 1847 and of 1850 reduced this risk by providing for the removal of the buildings on the north side, and facing the new street before referred to: notices were given, a Bill was prepared to be introduced into Parliament to carry out this essential improvement, but economy again ruled the day; the building could be erected without that cost being incurred, and the old houses in Rolls Buildings, the depôt of the London Parcels Delivery Company, and (till recently) a smith's forge, remained in close proximity to a building which should as far as possible be isolated.

The removal of the colonnade of The Quadrant, Regent Street, afforded Mr. Pennethorne an

opportunity of skilfully devising an elegant arrangement of balcony, which redeems the meanness of appearance of a range of shops, and gives a certain dignity to the street. Additions to the Ordnance Offices, Pall Mall, followed, and elaborate designs for a new War Office on that site were prepared. The removal of the excise department of the Inland Revenue from Broad Street to Somerset House gave rise to the necessity for enlarging that building, and a new wing facing Lancaster Place was decided on. Mr. Pennethorne, at once sacrificing his own fancy, thoroughly studied the work of Sir William Chambers, and has, in the most happy manner, added another façade to that noble building. On the completion of this work in 1856, seventy-five of the leading architects of the metropolis presented to him a gold medal in commemoration of the success which he had achieved. About this time he was fully occupied with architectural work of varied character, the most important being the new state ball room, supper room and galleries at Buckingham Palace, a suite of rooms of high importance, and specially to be noted for the richness of decoration: the re-construction of the central portion of the National Gallery, providing in the space occupied by the old hall and staircase; new staircases, a sculpture room for the Royal Academy and a fine gallery for the national collection; the new office for the Duchy of Cornwall at Buckingham Gate; the District Post-office, Pimlico; new stabling and extensive alterations at Marlborough House; the library of the Patent Office, and many other works were executed between 1850 and 1869.

Mr. Pennethorne was also much occupied during that period with designs for intended public works of great magnitude, especially for the National Gallery, not only on its present site, but for the Burlington House site, and one in Kensington Gardens. Several series of designs were also prepared for public offices in Downing Street, and, before the great competition, he had prepared designs for the concentration of the public departments on the site extending from Downing Street to Great George Street; and he was also one of the invited competitors who submitted designs for the Albert Memorial. Thus situated as a servant of the Government, debarred from all those opportunities of distinction which private practice could have afforded, his professional career may be considered to have been one of continually recurring disappointment; employed to carry out his conceptions for improvements in a mutilated and fragmentary form, and ever on the eve of executing some grand work worthy of his skill, and which might hand his name down as a great architect, the hour for realization of his aspirations was ever deferred. Still he worked on under great discouragement, and faithfully performed his duty to his employers, whether in the Office of Works, of which only I have spoken, or in the not less important, if not so prominent, office which he held as Architect to the Land Revenues of the Crown in London, and professional adviser to the Commissioners of Woods in charge of those estates; but the one opportunity was afforded to him, and his last work, his most complete and most successful, the University of London, will ever testify to his ability.

The history of this design is somewhat curious, and deserves to be recorded. The Government having purchased Burlington House, and the provision of accommodation for the National Gallery and Royal Academy having become urgent, it was proposed to remove the National Gallery to a new building on the Burlington House site and surrender the building in Trafalgar Square to the Royal Academy. Accommodation was also required for the learned societies to be removed from Somerset House, and for the University of London—rapidly growing into great importance: after long deliberation, it was finally determined to retain the National Gallery at Trafalgar Square and to appropriate the Burlington House site to the other bodies, the learned societies to occupy a new building (now approaching completion) in front of Burlington House, next Piccadilly; the Royal Academy to take Burlington House, and to build new galleries in the rear; and the University of London to occupy a building to be erected on the northern portion of the garden next to Burlington

Gardens. The University of London being simply an examining body granting degrees, the requirements of the Senate were few, the chief being a public theatre for lectures, granting degrees and other similar occasions; a large examination hall and library; examination rooms of special construction and arrangement for chemistry and anatomy; several minor examination rooms; a Senate room, &c.; and all these were symmetrically arranged with much skill, and the plans were approved by the Senate in April, 1866. The elevation then proposed was Greek in character, dignified but somewhat plain. On the accession of Lord John Manners to office as First Commissioner of Works, he desired a change in style, and in accordance with this wish Mr. Pennethorne prepared what is known as the Italian-Gothic design, which, in August, 1866, was approved by the First Commissioner. The foundations were at once commenced, the working drawings for the building proceeded with, and in February, 1867, a contract for the erection of the block of examination rooms in the rear and the main building up to the first story was entered into; but the design for the elevation having been shortly afterwards submitted to the Senate, exception was taken to it, and on the vote for the grant of the money required coming before the House of Commons, it was decided that the building should be of a design to harmonize with Burlington House. The works, so far as affected by this decision, were accordingly stopped in April, 1867, and on the 30th of that month the design from which the building has been erected was placed in the library of the House for the inspection of members. This being approved, and the money voted, in the following July the preparation of the working drawings was ordered, and in March, 1868, the contract for the completion of the carcase was entered into, supplementary contracts, varying from that of February, 1867, having in the meantime enabled the architect to proceed immediately, and with but little delay with the lower story of the building. In June, 1869, the fourth contract (for the completion) was let, and on May 11th, 1870, the building was formally opened by Her Majesty the Queen. I may observe that the contractors were Messrs. Jackson and Shaw, and that notwithstanding the changes of design varying their contracts, they carried out the whole without difference or dispute, and their accounts were closed almost contemporaneously with the completion of the work.

The principal features of the interior are the great examination hall and library, 72 feet by 53 feet and 41 feet 6 inches high, occupying the entire west wing; the lecture theatre, 72 feet by 56 feet and 52 feet 6 inches high, occupying the entire east wing, and affording sitting room for about 800 persons; also the grand staircase and spacious connecting corridor. The theatre is a remarkable success, and, as in like works previously executed by Mr. Pennethorne, every person can see and hear, and is, in fact as well as name "a *spectator* and *auditor*" of the proceedings on the platform. But, however convenient and admirable the interior arrangements may be, to the mass of the general public the exterior of such an edifice is of most interest, and this affords one of the few instances this country possesses of the graceful combination of the sister arts of architecture and sculpture. The picturesque grouping of the building, and the happy effect of its composition are well seen when, on a summer afternoon, the setting sun lights up the front, which unfortunately has a northern aspect, and is thus placed at a great disadvantage. The effect of the free use of red Mansfield stone in combination with Portland has, by the action of the atmosphere, very much toned down, and it might be worth the consideration of the authorities whether a periodical washing of the whole, removing the deposit of soot before it had time to harden would not be desirable.

The sculpture is not simply decorative, but may be deemed to be commemorative and closely in relation to the objects of the Institution. Thus, on the portico, the four sitting statues, by Durham, represent in the persons of Bentham, Harvey, Milton, and Newton, the four Faculties of the University; continental science is represented by the statues of Leibnitz, Cuvier and Linnæus, executed by Theed, and placed in the niches of the east wing; while McDowell has represented Adam Smith, Locke and

Bacon in the corresponding niches of the west wing. The propriety of placing statues on the parapets of buildings has always been open to discussion, and the success of this experiment will, I hope, lead to other not less fortunate attempts. On the east wing stand statues of Galileo, Goethe and La Place, by Wyon; and on the west wing Hunter, Hume and Davy, by Noble; the six statues on the centre building being those of Galen, Cicero and Aristotle, by Westmacott; and Plato, Archimedes and Justinian, by Woodington. The entire cost of all this sculpture was certainly under £4500. and it is seldom that expenditure in decoration has been so well and so wisely applied.

Shortly after the completion of the University, the reorganization of the Office of Works having led to the abolition of the offices which he held, Mr. Pennethorne retired from the public service on a liberal but well-earned pension; and in November, 1870, his great services received higher recognition by the conferring of the honour of knighthood. He did not long enjoy his retirement; on the 1st of September last, having visited London in the apparent enjoyment of full health, he returned home, and was suddenly struck down by death, thus, almost with the termination of his official employment, passing away from this world.

Elected a Fellow of this Institute in 1840, he was not often able to attend the meetings, but always took a lively interest in all matters relating to the prosperity or interest of the profession. A man of retired and studious habits, engrossed in the duties of his office and mixing but little in society, he sought not those honours which he might well have claimed; he was, however, a member of the Academy of St. Luke, at Rome, and the Society of Architecture at Amsterdam. On May 29th, 1865, he was honoured by receiving the Royal Gold Medal for Architecture, placed by the Queen at the disposal of this Institute—but a perhaps greater and more gratifying honour had been in 1857 previously bestowed on him, under circumstances which merit notice; soon after Sir Benjamin Hall had taken office as First Commissioner of Works, he commenced an inquiry into the conduct of all the important works which had been under the control of that department; and this enquiry was directed, as regards Mr. Pennethorne, in such a manner as to cause him grave annoyance; while about the same time attacks of another character were made on him in public journals, and although the fully detailed reports which he made, and which were laid before Parliament, amply vindicated his conduct throughout every stage of very complicated proceedings, his sensitive nature was deeply grieved by these incidents; and the address of congratulation on the completion of the west wing of Somerset House, which in July, 1856, seventy-five of his brother architects presented to him, was a source of great satisfaction, as testifying that if the then First Commissioner and others did not appreciate the eminent services which Mr. Pennethorne had rendered, his professional brethren were fully aware of his merits, and desirous to publicly bear testimony to his ability and his anxious attention to protect the public interests entrusted to his care. Accompanying this address was a medal, struck in gold for the occasion, which was presented to Mr. Pennethorne, by Earl de Grey, then President of this Institute, on the 18th of May, 1857. A report of the interesting proceedings on this occasion is printed in the Appendix to the Sessional Papers, 1856-57, annexed to which is a statement of works on which he had been engaged; and in the *Builder* for December 1st and 8th, 1866, and also September 16th, 1871, further details relating to the subject of this memoir will be found.

A critical examination of the works of Sir James Pennethorne would exceed the limits of this paper, but will, I hope, not be overlooked in the discussion, and I entertain so deep a respect for his personal merits, that I am unable worthily to speak of them. The address of 1856 admirably expressed the feeling of the profession towards him; and although his courtesy and unflinching rectitude could not shield him from attack, he filled a very difficult position and sustained the duties and responsibilities of an onerous office with great honour to himself, and by his kindness of manner

and straightforward honesty of purpose, won the respect and esteem of those with whom he was brought in contact.

MR. CHARLES BARRY, Fellow.—I rise to propose a vote of thanks to Mr. Cates, for his interesting paper. I do not think it is quite desirable, or perhaps hardly in good taste to accept his invitation to enter into a critical disquisition of the works of our late colleague. In Mr. Cates, who knew him so intimately, Sir James Pennethorne has met with an able eulogist, and I am quite sure all amongst us who knew him in a less degree can, in the degree in which they knew him bear witness to the truth of all that has been said of him. As to his rectitude, universal courtesy, and kindness to those who had to do business with him in his official capacity, everybody who has been placed in that position, as I have been myself on various occasions, can testify. On some of those occasions it was his pleasing duty to consider matters of common interest between us; on others it was his duty to criticise and perhaps oppose the views which I took, but on all occasions, whether of professional variance or difference, the same courteous manner and strict integrity characterised all his proceedings. I was one of those who joined in the address and subscription for the gold medal to commemorate his work at Somerset House; and I remember one great reason (in addition to our sense of his personal merits) for that which most of us had, was a strong feeling that Sir J. Pennethorne was beiug unfairly and uncourteously used by those under whom he acted. I need not now say more than to express my entire sympathy with all that has been stated of our late friend and colleague, and with the sentiments to which Mr. Cates has given such good expression in his paper.

MR. TALBOT BURY, Fellow.—I feel great pleasure in seconding the motion, and the more so because Sir James Pennethorne was my oldest friend. We were pupils together with the first Pugin. I worked with him, remained his friend, and saw him shortly before he died. I feel that what has been addressed to you by Mr. Cates this evening, has been so carefully prepared and expressed with so much truth, and with such completeness, that I think nothing could be added to it. Our President, in his address at the opening of the session, drew attention to Sir. J. Pennethorne's kindness, modesty, urbanity, and talents. I feel that I am unable to add anything to what has been already said, and therefore I beg most feelingly to second the vote of thanks to Mr. Cates, for his pains in preparing this memoir of our late friend, and for the happy way in which he has brought it before us.

The CHAIRMAN.—It is my pleasing duty to convey to Mr. Cates the thanks of this meeting. Most of us knew and had the greatest respect and regard for Sir J. Pennethorne personally, and I as an individual member entertain the highest opinion of his works. I have always regarded them as being of great merit, as evinced by his last great work in Burlington Gardens, but perhaps more particularly by the Museum of Economic Geology. I can bear personal testimony to his urbanity, kindness and strict integrity in all matters of business in which I have been brought into contact with him. It is gratifying to have the memory of one who has so recently left us revived in this pleasing manner. We all regret his loss, and it is most agreeble to us to have had such a memoir as has been presented to us to-night.

MR. EDWARD HALL, F.S.A., Visitor, said:—I have for many years taken interest in the career of Sir James Pennethorne, and in the progress of London improvements. In the year 1857, I was employed by Mr. Charles Knight to contribute to the *English Cyclopædia*, biographies of living men; and amongst the names selected were those of Mr. James Pennethorne and Mr. John Pennethorne. I have now in my hand some notes which Mr. James Pennethorne wrote for me, at my request, of his early life; and in the *Cyclopædia* you will find a few facts and dates which have escaped Mr. Cates's attention. But I wish, more particularly, to direct further attention to the difficulties in which Mr. Pennethorne was constantly placed in treating Government Works. During the whole time those works were under

consideration, or were being carried into effect, he was thwarted in a manner which one could hardly conceive without close study of the subject, such as, I may say, I have myself given it. You will find some of the results of those difficulties, in the line of Bow Street and Endell Street, and in that of which Coventry Street and Long Acre were to form part. If those lines had been carried out as Mr. Pennethorne designed them, we should not have had that corner which there is, where Coventry Street joins New Coventry Street, where stands the restaurant called the Cremorne Branch, jutting out and interfering with the direct route of the traffic. We should have had a broader route, and there would not have been the danger that there is on every opera night, in Coventry street. Nor would there have been the projection of the corner of Drury Lane and Great Queen Street. We should have had a tolerably straight line, taking in Coventry Street, Long Acre, and Great Queen Street, without the present twisted junctions. The actual defective arrangements were owing to the excessive anxiety for diminution of expense, and to the absence in Mr. Pennethorne's superiors, of his forethought as to future requirements, and his judgment as to modes of proceeding. Thus, only one side of what is now Endell Street was dealt with; and the other side remained as inferior property, whilst there were formed the awkward turns at the north and south ends of the street, instead of the line being made straight from Wellington Street to Bloomsbury Street. But it will surprise those who have not paid attention to the history of this subject, to be told that it was argued by recognized authorities in these matters, that a crooked line was better than a straight one. It was maintained by Mr. Higgins, a surveyor of the day of some eminence, that it was much better that the traffic should take a turn in the case of any crossing of streets, than that it should cross at right angles. The consequence was that the suggestions of Mr. Higgins and of Mr. Richard Lambert Jones, the latter a great man in the city in those days, were preferred to those of Mr. Pennethorne; and it was also owing to their influence that Middle Row, Holborn, was allowed to remain so many years as it was. I wish also to say a few words, as to the tone of criticism of Sir J. Pennethorne's works in the newspapers. I do not just now allude to the professional journals, but to the general press. I think it is a serious matter that there should appear in public organs in which great confidence is felt by the general public, criticisms and statements such as have been put forth concerning Sir James Pennethorne and his works.

It is a matter which seriously concerns the profession at large. In the *Globe* of April 17th, 1869, there is a short article, containing such a number of gross mis-statements, that I think it will not be out of place to quote them:—

Mr. Hall read the article; which, besides perpetrating errors in the names of eminent men of different periods, referred to "the gorgeous and undescribable elevation," bearing "such an extraordinary resemblance to the conventional design displayed on the cover of a box of German bricks;" to the composition of the front as difficult to speak of "with respect or even courtesy," and as "about as bad as it is easy to imagine anything of the same class and general character to be;" to "pillars, pilasters, panels, perpendicular lines, and lines that ought to be perpendicular and are not," as waging "remorseless warfare with cornices and horizontal lines generally, to the utter destruction of harmony;" to "circles and semicircles" that "co-mingle," and recesses confusing "the vision until the prevailing impression comes to be one of strange discomfort and disappointment;" to "a superabundance of sculpture and statues of full proportions," and to figures, some standing, and some sitting, or "all more or less objectionable in themselves," as forming "a collection of statuary, only somewhat less offensive, chiefly because less obtrusive than the figures in Westminster Hall;" and to the "desiderated" beauty of the interior, as requiring to be "applied on the 'enamelling' principle in the form of plaster."

Now (continued Mr. Hall) I hope I have not unnecessarily occupied time in reading this. I could

produce a great number of articles of the same stupid character, which are read by the public as gospel, and which tend, in conjunction with the opinions we hear expressed in Parliament, to the serious injury of our art in this country. I could quote from the *Daily News* an article, the writer of which having occasion to notice the exhibition of the Royal Academy, and finding himself in Burlington Gardens, proceeds to describe the front of the University of London, as though it were the front of the Royal Academy. I think really it is not out of place that we should notice such matters as these. I consider that by these mis-statements, not only are the characters of eminent individuals frequently traduced, but that we are all of us placed under a sort of obloquy which, helping to depreciate the profession in the eyes of the public, also greatly contributes to reduce the importance and the valuable influence of our art in this country.

Professor KERR, Fellow :—One thing that occurs to me with regard to the late Sir J. Pennethorne is, that he may be called the last of our Government architects. We may, therefore, consider the question (which is one of great importance to all who take an interest in the architecture of London and its improvements, in the widest sense of the term), what is to be the condition in future of that description of business, which Sir J. Pennethorne was the last architect who is to be recorded as having looked after. Sir J. Pennethorne, as I understand, was not only the Surveyor over the Crown property in London, but he was the adviser of the Government with respect to matters of public architecture in London, in the same way as the Government were formerly advised by Mr. Nash, Sir John Soane, and Sir Robert Smirke. The functions were exercised by those three gentlemen conjointly, and the complaint was made, I think, against them that, being employed to afford the public the benefit of their combined advice in all cases, they divided London into three portions, and each took one.* Mr. Pennethorne followed in the office which those three gentlemen had filled, and, after life-long service, he was, as we all know—and it is best to use plain language—at length dismissed—officially and peremptorily dismissed, not on any personal or professional ground, but because the present Government objected on principle to recognise the functions which he exercised. It was a demonstration on their part—at least it is difficult to interpret it otherwise—against the admission of proper professional architectural advice for the future. We have now to understand that the conduct and control of architectural affairs on the part of the Government is to be henceforth managed without the advice of an architect. If the demonstration, as I call it, meant anything it meant that; and if anything had been wanting to fix upon the public mind that interpretation of it, I think certain occurrences which have happened since are quite sufficient. When we look, for instance, at the way in which the new Post Office is being carried out, that of itself speaks intelligibly enough. But to pass to another point:—We lost in the late Sir J. Pennethorne a man of special ability and special education, who seems to have devoted his lifetime—and that apart altogether from considerations of specific employment—to the great question of the improvement of the metropolis,—and not merely its improvement in the sense in which the phrase is generally used—such as merely cutting a new street through a back slum, and making a new line of thoroughfare—but, as far as he dared, the architecturesque improvement of the metropolis generally, which is a consideration of so much importance in London—as compared, for example, with Paris. There is a question which I have often heard asked, but have never yet heard properly answered—viz:—Why is it we in London find it utterly impossible to do as the Parisians have done with regard to their streets? We are richer than they. We have greater necessities with regard to traffic. The property affected, I have been told on the best authority, is not, as many of us may have supposed, more valuable than theirs. And yet we find they are able to cut straight lines in

* I am reminded that it was the case of the Houses of Parliament which put an end to this. Sir R. Smirke was at first entrusted with the preparation of a design; when Sir E. Cust procured, by parliamentary intervention, the celebrated competition which resulted in the appointment of Sir C. Barry.—R. K.

the precise direction in which they are felt to be desirable, and so to form grand thoroughfares through Paris in all quarters; and though it may be the fact that embarrassment has ensued, yet there is no appearance, even in this the darkest day Paris and France have ever seen, of the dreaded result of an actual crisis. I have always felt disposed to consider that money laid out in the improvements of a metropolis is money well invested for the people. True, it may not bring a direct return in the shape of a money profit, but it brings profit in many an indirect way, which makes the outlay what is called a successful investment; and I think it is a pity our financiers and public men of business are so unwilling to take that view of the question. When a common tradesman builds new premises, or puts a new shop front into his house, he does not expect to get a direct return for it in money. He makes his place more attractive and convenient, and he knows that his business will improve in various unexpected ways as the consequence; so that he makes it answer on strictly businesslike and financial grounds. In the same way I contend that the public of the country, looked upon as a community in business, will find it a judicious investment, and not a mere waste of money, to pursue the architectural improvement of those great centres—and particularly London—in which business is carried on. By recent arrangements, as we know, the future improvements of London—at least in their purely utilitarian bearing—are to be a portion of the operations of the Metropolitan Board of Works. The question, however, arises—who is to take the initiative in those projects which such a Board can scarcely be expected to initiate. Our First Commissioners of Works, we architects may be excused for suggesting, are in this view of the case of no use whatever. It is notorious that our First Commissioners, one after another, have been mere politicians, who, having what is called a claim upon office, have been put into that particular position to work their way up, if possible, to some higher post in the scale of dignity. I humbly submit that is not the best way in which to deal with the architecture of London, or with the outlay of the public money, in any kind of building: and I think it may possibly be ultimately found to be necessary—I hope it may—to have something like a proper and responsible professional authority in connection with the Government and Parliament, which shall take into consideration all questions of the kind; and especially those which affect Government property, and the great thoroughfares in which the Government buildings are situated, as in the case of the Whitehall quarter; and I venture to say it is impossible to accomplish anything upon a dignified scale, unless there is some such agency provided to initiate intelligent proposals with something like authority. I must say the Metropolitan Board, so far as it has gone, in street improvements, has succeeded to a greater extent than many of us supposed possible a few years ago. I think we must all agree that that body deserves especial credit for success in respect of the several grand lines of thoroughfare, which have recently been opened. But I think there are some things which the Metropolitan Board cannot be expected to do—which the Government must do if they are to be done at all; and the question is a most important one—how the initiatory steps are to be taken, now that the office of Government architect is swept away. I do not see in the policy of the present First Commissioner or in the new machinery of the Office of Works, anything approximating to such an agency, as would serve to initiate public works in an efficient manner. With regard to the personal and professional character of our late friend, the subject of this memoir, I have been much pleased to hear the remarks which have been made respecting him. I have been brought in contact with him on various occasions, and I was struck by the extreme kindliness of manner and integrity of purpose he always displayed. I think Sir J. Pennethorne has been a credit to us and to the country. By the way, when I look at his latest work in Burlington Gardens, one thing occurs to me, as a matter scarcely of criticism, but of artistic curiosity. It is this:—(and what my friend Mr. Hall says, with regard to some foolish comparison of it to a box of German toy-bricks, enforces what I am going to say)—

I never saw a design, which, on paper, conveyed so poor an idea of the effect in the solid as that one. I do not know why it is so, but there is something about all the drawings I have seen, which gives the feeblest possible idea of a building, in reality, so massive and elegant. The bold projection of the portico, the fine effect of the sculpture, and the solid breadth of the facade as a whole, all commend themselves to the mind of the critic as constituting an admirable architectural design; and I should be glad to hear if anyone can tell me, why a work so successful in the solid should always bear a comparatively poor appearance in the drawing, and especially in elevation. This shows, at any rate, that one has a right to distrust the art of draughtsmanship in more ways than one.

Mr. G. HERBERT WEST, Associate.—If I may be permitted, as a very young member of the profession, to say a few words on this subject, I would remark, in reference to the observations that have fallen from the last speaker, that in my opinion the different conditions in the laying out of new streets in London and Paris arise not so much from differences in the cities themselves as in the government and the nature of the people. In this country we can never expect to have an autocracy such as that under which Baron Haussmann carried out the improvements of Paris on so grand and gigantic a scale seconded by an irresistible law of expropriation which served more especially to make the fortunes of many who were engaged under it. The first plans carried out were those for streets which were not designed by M. Haussmann, but which were decided upon under the rule of Louis Philippe and the Republic. The plans were divided into three sets or networks, which we might characterise as the really desirable, the useful, and the extravagant. The first, which had been decided on before 1859, comprised the Central Markets, the Boulevard Sebastopol, the Rue de Rivoli, and the opening up of the city. The second decided on in 1859, included the Boulevards Prince Eugene, Chateau d'Eau, and Malesherbes, &c., Pont de l'Alma, Avenue Marbeuf, &c., Rues de Rome, de Lafayette, &c., the Parc Monceaux, and the Bois de Boulogne and Vincennes. The third network comprehended all the streets' round the New Opera, *i.e.*, the Rues Halévy, Auber, Scribe, Chateaudun, Quatre Septembre, &c., Boulevard Haussmann, &c., and on the left bank, the Boulevard St. Germain, and the Rues de Rennes, Guy Lussac, Monge, &c. The first set cost 272 millions of francs, the second 410, the third 615. Total, 1,297,000,000 francs equal £51,880,000.

Before the Boulevard Sebastopol was undertaken, there had been great discussion as to whether the existing streets, St. Denis and St. Martin, should be widened by buying up the houses and setting them back—whether an entirely new thoroughfare should be made. In 1859, partly perhaps for military reasons, the preference was given to the new boulevard. It was argued that interference with existing thoroughfares did more harm than good, and damaged trade, and that it was better to buy up houses in the back slums between two great streets, and drive a new boulevard through them. The difference in the nature of the traffic of the two cities is such that in London you cannot drive streets at hap-hazard through old quarters of the town and be sure of their bringing in a profit upon the outlay. In Paris if they form a new street in which the ground floors of the houses are shops, as is almost invariably the case, they are sure to meet with occupiers, and the upper floors will let in flats. So there is sure to be a good return on the money spent. But if you were to drive a new street through Drury Lane you may be quite certain no one would live there, shop-keepers would not take the shops, and the houses would not let in flats or as respectable lodgings, but the street would remain as poor as before. In Paris the tradesman occupies the shop and the rooms behind it or at the top of the house, and in intermediate portions you have all sorts of people living, from the most wealthy to the poorest; and you are sure to have a traffic through the street, for Paris is a round city, while London is a long city. Our great avenues of traffic are by Oxford Street and the Strand; that in the other streets goes in no particular direction, but in Paris wherever you drive a new street you are sure to have traffic through it, since it forms

one of the radii of a circle. This is clearly seen in comparing the omnibus maps of Paris with those of London. When a railway was proposed for Paris similar to our own Metropolitan Railway, it was objected to because the traffic was not sufficiently definite in its direction for it to be likely to prove of real service. In London you may have passage streets, but nothing more, however good the houses may be. In Paris you are certain to have a street more or less of palaces: some of the streets are very well inhabited, and all more or less bringing in good rents, and you cannot make sure of that in London. Since our Government have taken up the system of renouncing the employment of architects, you cannot have men in London corresponding to Baron Haussmann, or the present Préfect of the Seine, with a body of architects working under him. In short, the difference of conditions is so great that you cannot fairly compare the two cities.

Professor KERR. May I be allowed to ask Mr. West who has spoken so well on this subject, one question? Sir W. Tite once told us that the loss upon every new street opened in London was from 60 to 65 per cent., and when the question was put what it was in Paris he said he has ascertained it was as near as possible the same. Can the gentleman give us any information as to that?

Mr. WEST.—I cannot speak to that. If I had been aware that the discussion would have taken the turn it has, I would have better prepared myself on the subject. I should imagine the loss on new streets in Paris is not so great as that. The difference must depend upon what streets you compare.

Mr. EASTLAKE.—What is the difference in rents?

Mr. WEST.—Enormously higher in Paris. There is one street built in the time of Louis Philippe upon the London principle, of setting back existing houses, I mean the Rue Rambuteau which runs through the old part of Paris. The Boulevard St. Michel was certain to be a great line of traffic. The Boulevard Haussmann is perhaps the only great street without shops which could be compared with our streets of private houses. It is only half finished, and other streets have been left in such a state of incompletion that you cannot take them into account. The Boulevard St. Germain has been begun at both ends and in the middle, but left unfinished because it will require 12 millions of francs to buy up the Ecole de Medicine to complete it. Some of those streets may be gone on with, but I should scarcely think M. Thiers will finish the streets round the New Opera.

Mr. E. HALL.—If I may be allowed I would say a few words with reference to what the gentleman who has just spoken has said so well. I have paid great attention to this subject, and especially during the time that the most important works were going on in Paris. I was in Paris from 1860 till towards the middle of 1862; and I think I can supplement the information the gentleman has given us on two or three points. The real reason why in Paris the improvements are, as in my opinion, so much more successful than in London, is that in the former city there is preliminary design or *plan*. That is to say, there is general plan and principle observed, dealing with the whole of the French metropolis. In London there has been no general plan; for even Mr. Pennethorne's plans were only applicable to a small portion of the area of the metropolis, not to repeat mention of the fact that they were made under the greatest disadvantages. The principle in Paris has been that which was observed by Wren in making his well-known plan for the improvement of the city. The principle in each case was this:—Decide what shall be your centres, and then form main lines to and from them, and direct lines. Every capital city has three or four main centres, such as a commercial centre, a centre of pleasure, a fashionable centre, and a centre of government; and it is necessary to decide upon these or to treat these as having been decided before you arrange your main lines. In Paris, pleasure is of greater importance than it is in London. Therefore, having decided to remove the opera house, it was a main point to make routes converging to the place fixed upon as the site of the New Opera. I disagree with

the last speaker in what he said with regard to the utility or non-utility of the streets round the Grand Opera. I think those streets have been well devised. I may mention, for example, the Rue Lafayette. Any one looking at the plan of Paris will see that the principle adopted by Wren has been carried out. though for the whole metropolis and suburbs, instead of the design being confined to one portion of the metropolis. I agree with the gentleman that some of the recent improvements of Paris are almost extravagances. No doubt a great deal has been done to keep the population employed. Still there is in Paris, I believe, a much greater return for the expenditure than people here are in the habit of supposing; and I am inclined to think when there is supposed to be a difficulty in getting occupation for buildings in new streets in London, it is forgotten that part of the general demand of the present day for places of residence is one for residences for the middle and "lower middle" classes; but in too many cases we erect comfortless buildings, badly planned and ill-constructed by speculative builders, and there is no inducement to occupy them. People have been driven to reside in the suburbs; but there is a growing feeling of disadvantages which attend suburban residence. If we had properly planned buildings in properly planned streets, no doubt they would be occupied; and the improvements would give that return on the investment to which Professor Kerr has so well alluded.

Mr. R. Phené Spiers, Associate, said:—As far as our experience has yet gone there seems to be a decided distaste on the part of the English public to living in flats. There are some in Victoria Street, and though they have been built 12 or 14 years, I am not aware that there has been such a demand for that kind of lodging as to call for a fresh supply. I can bear out what Mr. West says as to the facility with which shops and apartments in new streets in Paris are taken possession of. On the appearance of a new street, with the road hardly finished, and while the street itself is not much known, it is natural to suppose that the shops would only be taken by an inferior set of shopkeepers, who commence business somewhat in the way of the American stores, but it will be found that after the lapse of two or three years the shops are tenanted by respectable tradesmen; much money is laid out on them, and they form an additional attraction to the fine architecture of the street which has been opened. The rents of these flats far exceed the rent of our houses in London, even in the suburbs of Paris. In the outside of the outer line of Boulevards, a suite of five or six rooms on the third or fourth floor cost more than a 12 or 14 roomed house in the centre of London, and when you come to the Boulevard St. Michel and Boulevard Strasbourg, the prices obtained are immense. To a certain extent we may set against that the expenses which Londoners incur, by living in the suburbs, in going to and from town daily. Some live at distances which cause an additional expense of £20 or £30 a-year in railway or cab fares, and that does not include the family travelling expenses; and if these are added to the rent of the house in the suburbs of London it would bring it up to about the same price as is obtained for the flats in Paris. The French have been accustomed to be satisfied with a much smaller quantity of everything than we are. They use very little water, and do not always see the necessity for a bath at home; it is the same with regard to food and everything else. The rooms are only just as large as is necessary. They have not large families or it would be difficult to understand how they could manage with such small accommodation. As a rule these flats contain not more than a quarter the space which there is in our English houses.

There is one remarkable point connected with France, interesting at the present moment. I was afraid the enormous expenses of the late war would cause some diminution in the amount granted by the State to the schools of art, but I am delighted to find that not only the Ecole des Beaux Arts, but all the other schools of Paris, are still maintained in their former position, and this constitutes a considerable item in the expenditure of the nation, and when I was last in Paris placards were put up announcing that in every arrondissement and sub-arrondisement schools had been established for

gratuitous instruction in drawing. I do not hope for such a thing in London, and I am afraid it will take a long time to educate the people of England in the fine arts up to the same point as is now being done in France, and that may account for the apathy which exists here (not to say opposition) to the forming of new streets and the lining of them with fine architectural buildings.

Mr. E. R. Robson, Fellow.—Professor Kerr has asked, why it is that in London we cannot carry out public improvements on the same comprehensive scale as has been done in Paris? To that it may be remarked that in this country we are subject to the provisions of the Lands Clauses Consolidation Act of 1845, which are applicable in all cases of public works and improvements, just as in the case of railways. The result is that in the case of opening out new streets you cannot obtain just the amount of property which you require and no more, if there is any objection on the part of the owner. [Professor Kerr.—You must take the whole.] In Paris the public improvements have been planned as one great and complete scheme. Sir W. Tite told us that the cost of improvements in Paris was considerably less than in London.* [Professor Kerr.—No; much about the same.] What has been done in the way of improvements in London has been done on insignificant though expensive scale. In Paris they have a fixed tribunal to which all cases of purchases are referred, but under the Lands Clauses Act such a thing as taking the exact quantity of land you want is impossible. Two points have been stated with regard to the laying out of streets; one is that an absolutely straight line is best. For my own part I think that is questionable. In my opinion, where the bulk of the traffic is of a heavy description a slight *detour* is preferable to crossing streets at right angles. In Paris there is more light traffic than heavy. In making straight lines of streets we reduce the thing to the point of convenience, and art is nowhere. Take the case of St. Martin's Church; convenience would ignore such a thing, standing as it does partly across the line of St. Martin's Lane, but art did not. I do not myself hold with the notion that all new streets should be strictly straight lines. In Paris we find that every straight street requires an ornamental column at the end, and it is the column which is seen rather than the architecture of the street.

The vote of thanks to Mr. Cates was then passed in the most cordial manner.

Mr. Arthur Cates.—I am much gratified at the manner in which the memoir I have laid before the meeting has been received, and considering the close connection of Sir James Pennethorne with the improvements of London, I am not surprised that the discussion should have taken the course it has. The contrast, vast as it is, between the public works of Paris and those of London, is naturally a subject of great importance; but those who have spoken in terms of regret at the difference between what has been done here, and on the other side of the Channel, have forgotten one element; they have spoken almost as if this country was deficient in designers of taste and art: I protest that while our rulers or those who have the control of these matters, may be deficient in those points, there are plenty of men available who are competent for the task: the one great thing wanting has been funds, and in that respect London has been placed in a position different from Paris. Those who have not studied the map of London of 1805, can have no idea of the mass of tortuous lanes and miserable dens that have been swept away, where now we have valuable property, and some of the most important districts of the metropolis. The great work carried out by Nash which converted the narrow and tortuous lanes around old Swallow Street into the present noble thoroughfare of Regent Street, and the great improvements round St. Martin's Church, Pall Mall East, West Strand, &c., were carried out at the expense of the State, and it having been decided that the Land Revenues of

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* See the Paper read by Sir William Tite, "On the Paris Street Improvements and their Cost," 14th December, 1863, and since published among the Transactions of the Institute.

the Crown, from which the funds had been so wisely provided, should no longer be used for such purposes, the further progress of such works was suspended. I have indicated in my paper the manner in which it was desired to continue those improvements, but the only funds at disposal for the purpose were those arising from the coal duties, &c. For the works already executed, those dues were mortgaged for years, and further sums were obtained by further mortgages of those imposts. The funds thus raised were soon exhausted, and there was no means of raising other monies. The policy of the Government had been to keep London in a state of helpless infancy, cut up into little districts, ruled as regards parochial interests by vestries, but without the power of combination and joint action, which alone could lead to the execution of works worthy of the metropolis. The constitution of the Metropolitan Board was a very great advance on this state of things. That Board in time acquired power to raise money by taxation, and we have seen the result of this control of funds, in the construction of new streets, projected many years ago, and the formation of the embankment, which is a work equal to anything in Paris, or any other city. We may assume, that if London had been favoured with the means of raising money that existed in Paris, we should have had works which if not equal in brilliancy, would have been equal in utility to anything in Paris. Paris has been more fortunate, the *octroi*, a ready means of raising funds, was in full operation:—at the end of 1852, the loans raised by way of annuity to meet the expenses of the occupation of the city by the allied armies in 1815 expired, but in place of the agitation which would have here arisen, to reduce the taxation, and sacrifice the great interests of the City to a paltry gain for the present time, the wise administrators pledged those duties for further terms, and by the fund so raised and further loans, based on the credit of the municipal revenue, commenced those great works to which allusion has been made.

It was the large sums thus raised which gave the first impetus to the improvements carried out by Baron Haussmann. Then again in France the State generally acknowledges its obligations to the capital, by contributing one third, more or less, to the improvements carried out, which affect localities in which the State and the whole country may be interested. Thus the works around the Palais Royal, and the east side of the Louvre were constructed by the aid of large contributions from the State. If you compare the two cities, you must do so on the same basis, and London will then hardly appear to disadvantage.

The Discussion having been thus brought to a close, the Meeting adjourned.

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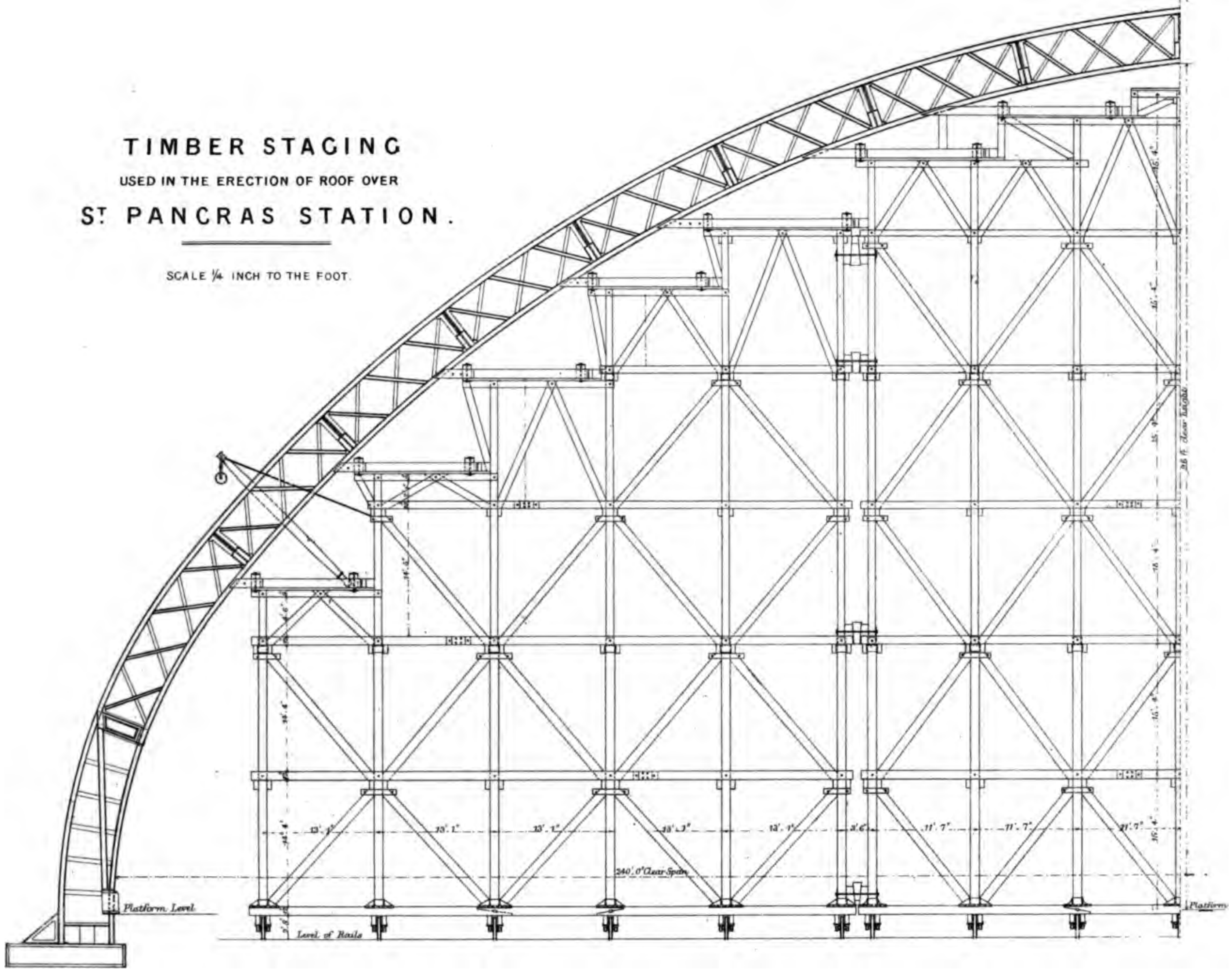

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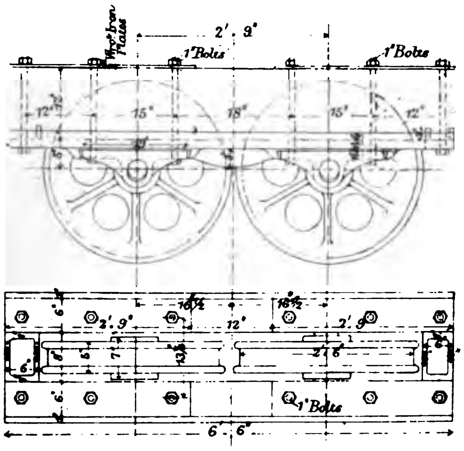

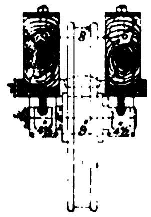

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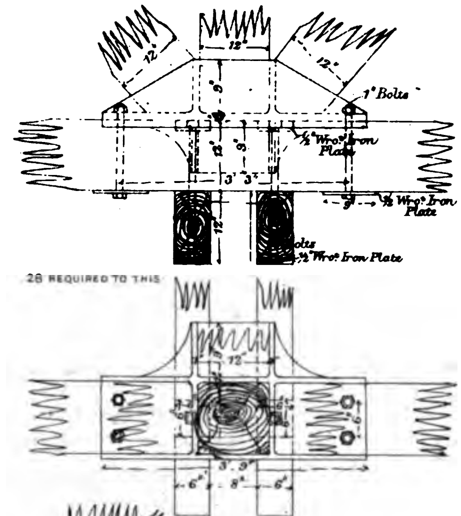

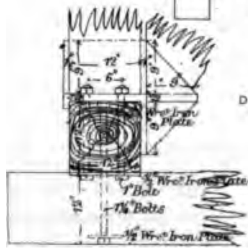

DETAILS OF JUNCTION BOXES &c. FOR STAGING.

Nº 2.

DETAILS OF TIMBER STAGING USED IN ERECTION OF ROOF OVER ST PANCRAS STATION, LONDON.

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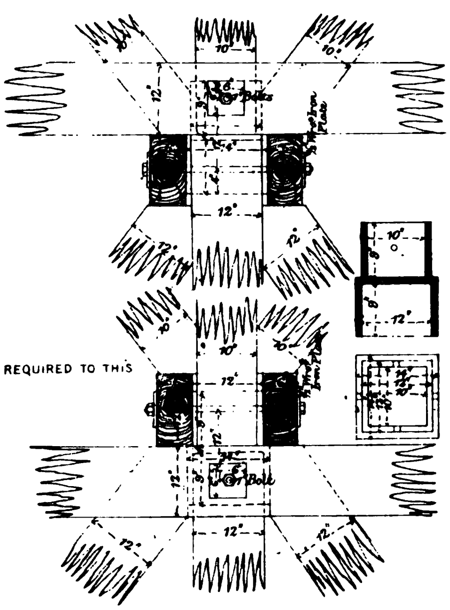
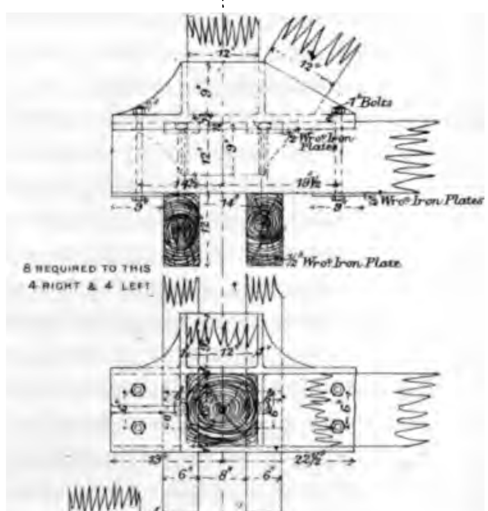
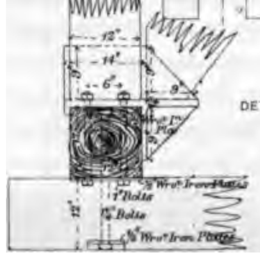


DETAILS OF COUPLING BOXES FOR STAGING

Nº 3.





DETAILS OF JUNCTION BOXES &c. FOR STAGING.

Nº 4.

Photo-Litho' for the R.I.B.A. by Whiteman & Bass, London.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 8th January, 1872, the following Papers were read, EDWARD I'ANSON, Vice-President, in the Chair:—

ON THE TRAVELLING STAGE USED IN THE ERECTION OF THE ROOF OVER ST. PANCRAS STATION.

By SIR JOHN G. N. ALLEYNE, Bart.

IN introducing the subject of the staging which was used for erecting the St. Pancras roofing, I wish to explain that I did not take it upon myself to press this subject on the attention of the Royal Institute of British Architects. I would not presume to take up the time of gentlemen who must necessarily have a number of projects well worthy of discussion and study continually pressing upon them.

The matter is now introduced by the express desire of the President and Council of this Institute, who, through Mr. C. L. Eastlake, requested that I would write the present paper—a request to which I most gladly respond, and cannot but feel highly gratified that the design of this apparatus and the arrangements connected with it should be considered worthy of the attention of such an important Society.

I will endeavour to make my paper as short as possible, consistently with explaining thoroughly the design and application of this staging, and this will be best done, I think, by a short sketch or history of the ideas and principles which led me to design and adopt it.

In estimating for such a roof as that at St. Pancras, the first and most important consideration was—how it was to be fixed. The principal rafters are 240 ft. clear span, and 100 ft. high. Sideways these main ribs or principals may be said to be without lateral strength. To consider the whole structure as a great wrought iron arch, and put a timber centering strong enough to carry it through the whole length of the station, would not do, because the enormous cost of the timber, and the labour of fixing it, would have involved too much expense. It would have been necessary to provide a centering for the length of eight principals: and this number is taken, because the wind ties, which start on the first principal, do not reach the wall, or get any connection to it, until that point is reached. Putting up such a centering, and pulling it down and building it up for the next, would have taken too much timber, labour, and time, and was in its turn abandoned.

It then became apparent that the best, most secure, and most economical system would be to put a centering on wheels right across the whole station wide enough to take two principals and leave room for the men to work outside. The principals being 29 ft. 4 in centres, the width of 40 ft. was adopted, and it was decided to make the staging move on wheels, from rib to rib, with such arrangement of its parts as would allow it to collapse after it had done its work at one rib and was required at the next. This was done by the timber slides to be hereinafter described.

I now come to this consideration:—The stage being fixed opposite the two first ribs, and these two ribs fixed with all their purlins, how are they to be held safely while the stage is moved to the 3rd

and 4th or the 2nd and 3rd? In the first instance, I saw no other way out of the difficulty than by having two stages, which plan I adopted; and the much improved method of dividing the stage into three parts did not occur to me until I began to consider that there might be some difficulty in moving such a great machine and keeping it square on the rails, the plan at this period being that the first stage should be left standing and bolted down to the floor opposite principals Nos. 1 and 2, which would be fastened firmly to the stage by the timber slides. The second stage would then fix three and four, and fasten them by their purlins and wind ties to No. 2, and move to five and six. When No. 8 was reached the wind ties could be fastened to the walls, and this part of the roof would be in all ways self-supporting. No. 1 stage could be moved up to No. 9 rib, and No. 2 could be rolled to forward No. 11, and four ribs could be worked on at once.

On considering the difficulty of moving these wide and long stages 40 ft. by 208 ft. 10 in., I determined to divide them into three parts, and move each part separately. The idea immediately struck me that I could by this system do away with and save the expense of the second stage altogether. By fixing the three parts together opposite to ribs Nos. 1 and 2, bolting them fast together and also screwing them down to the floor, and placing chocks under the main horizontal frames, the strain from the holding down bolts would be taken off the wheels, and all tendency to move prevented. The ribs Nos. 1 and 2 would be fixed with their purlins and all complete; the centre part of the stage would remain screwed fast to the floor, with its timber slides holding fast to the rib; the bolts holding the side pieces or wings to the centre compartment and those holding them to the floor would be removed, the chocks would be knocked out, the timber slides drawn in, and the wings would be free to move. They would move with their outer slides opposite No. 3 rib; their inner slides would hold on to No. 2 rib. They would then be screwed fast to the floor as before. The centre compartment would then in like manner be set free, and move up to ribs 2 and 3. The whole staging would again be screwed together, and to the floor as before, and No. 3 rib would be fixed. The wings would then move to No. 4, the centre would follow, and they would go on to the end of the station. I am sorry, however, to say that this plan of working did not suggest itself until the cast-iron couplings and wheels were made for both stages.

Main Horizontal Framing.

The main horizontal framing is formed of double timbers, the section being 6 inches by 6 inches; the axle boxes of the wheels are fixed to them, allowing the wheels themselves to run between the timbers. On these are laid the cross framing, consisting of timbers 12 in. square. These are firmly bolted to the lower double framing. On the upper 12 in. square timbers are bolted the cast-iron sockets for carrying the uprights and diagonals. Under the uprights the wheels, 2 ft. 6 in. in diameter, are fixed. Beneath those in the centre stage, where, from the height of the uprights, the weight of this part of the stage is increased, the wheels are doubled. In order to distribute the weight as evenly over the floor as possible, the wheels are so arranged as to have a weight of about five tons on each. Calculating from the centres of uprights, the whole three stages are 207 ft. 4 in. long and 38 ft. wide, giving a platform 208 ft. 10 in. long and 40 ft. wide.

Horizontal Framing Wheels.

The wheels are distributed as follows:—

Under the main uprights of the centre compartment are seven rows, of nine wheels in each row, making . . . . 63 wheels.

Under the side stages there are six rows, of five wheels in each row, making in all for the side stages . . . . 60 wheels,

which, in addition to those of the centre stage, make a total of . . . . . . 123 wheels.

The arrangement of the wheels, bed plates, and axle boxes is shown in detail on the accompanying drawings as well as by the model.

The horizontal framing is firmly braced in all directions by diagonal bracing, to prevent any tendency to twist.

The whole stage is fixed on nineteen lines of rails.

Uprights.

It will be seen from the model that two sets of timber uprights are placed under each rib. The weight of each rib with its purlins, intermediate purlins and wind ties is about 100 tons. There are in the *centre* compartment, under each rib, in all fourteen uprights, that is to say there are two rows with seven uprights in each, making twenty-eight uprights in all; in the side compartments the same double row of uprights is continued, there are six uprights in each row—two rows under each rib, making twenty-four in all; the other side compartment has the same number, we have then

In the centre compartment	uprights	28
In the east wing	,,	24
In the west wing	,,	24
In all		76

The dimensions of the uprights are 12 in. square.

They are 29 ft. 8 in. long; at this point they are fitted into a cast iron cap or socket, the lower part of this socket fits the first upright which is 12 in. square. The next tier is reduced to 10 in. square. The 10 in. square uprights are 29 ft. 2 in. long. At this point they are fitted into a cast iron cap, the lower part 10 in. square, while the top is reduced to 9 in. square, and this dimension is continued to the top of the stage. The whole stage is arranged as it passes under the ribs in steps or platforms, the height of these from the floor and their distance from each other is governed by the position of the joints in the main ribs.

Each of these platforms is fitted with the timber slides, one set for each rib. They clip the main rib firmly, having a lateral as well as an outward movement. They move laterally on the walings, and are not screwed down until the exact position of the rib is ascertained. Their outward movement is regulated by the folding wedges which are driven between them and the main uprights.

Uprights and Walings.

At a height of 13 ft. 4 in. from the rails the first line of walings is fixed; these run in a direction at right angles to the main ribs, or longitudinally with the station, the section is 12 in. deep by 6 in. thick. Immediately above them are the cross walings, at a height of 14 ft. 4 in. from the lower side to the floor After an interval of 14 ft. 4 in. again above these, at the point where the vertical timbers are to be reduced from 12 in. to 10 in. square, the second floor of horizontal bracing is introduced; at 14 ft. 4 in above this is the third set of walings, and at 14 ft. 4 in. above them is the fourth set of walings and the third horizontal bracing; at this point the timbers are reduced to 9 in. square. The centre compartment has seven sets of walings and 4 floors of horizontal bracing.

The side or wing stages at the highest parts have five floors of walings and three floors of horizontal bracing. The walings are in all cases double, *i.e.* there is one on each side of the vertical timbers.

Diagonals.

The whole stage is braced strongly with diagonals; these are so arranged as to abut against the main verticals and the walings. The walings being double and fixed on each side of the verticals, the

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strain from the diagonals is kept central with the verticals; a short cross piece is fixed across the walings at the point where they are fixed to the verticals to receive the end of the diagonals. To provide against the shrinking of the timber an arrangement is made for wedging up the diagonals, in all cases on the top of the diagonal. In this way any shrinkage of the timber is shewn by the wedges getting loose; if the weight of the diagonal rested on the wedges a shrinkage would not be observed until the diagonal itself was loose. The staging might give way and lead to considerable inaccuracies in the work. The diagonals are in all cases of the same section of the verticals against which they abut.

It will be seen from the drawings and from the model that the diagonals are so arranged that the heavy strains from the dead weights, and those produced by wedging out the slides which came vertically or horizontally on the walings and verticals, is distributed throughout the whole staging.

Quantities.

The iron work in the whole of the three compartments amounts to about 80 tons—50 tons of cast and 30 tons of wrought iron. The timber in the side stages is as follows:—

	Cubic Feet.
24 verticals 12 in. by 12 in. and 9 in. by 9 in.	1207½
27 tranverse walings 12 in. by 6 in. and 10 in. by 5 in.	1121½
26 longitudinal do. 12 in. by 6 in. and 10 in. by 5 in. and 9 in. by 4½ in.	1009
55 platform joists or walings 9 in. by 4½ in.	307
120 transverse diagonals 12 in. by 12 in. and 9 in. by 9 in.	1431
122 longitudinal do. " " " "	1418½
5 platform floors 3 in. thick	770
10 sets of timber slides	380
3 sets horizontal bracing	152
Battens, joint pieces, &c.	119
	7915½

For two wings 16,679 cubic feet.

Centre Stage.

	Cubic Feet.
28 verticals 12 in. by 12 in. and 9 in. by 9 in.	2157
45 transverse walings 12 in. by 12 in. and 9 in. by 4½ in.	1500
86 longitudinal do. " " " "	1443
44 platform joists or walings 9 in. by 4½ in.	320
184 transverse diagonals 12 in. by 12 in. and 9 in. by 9 in.	1949
152 longitudinal do. " " " "	1620
5 platform floors 3 in. thick	780
4 sets of timber slides	160
3 sets of horizontal bracing	72
Battens and joint pieces	154
	10,155
Wing stages (together)	15,831
Total in the whole stage	25,986

Timber Slides.

The timber slides, one of the most important, and, as they proved in practice, the most useful and handy part of the apparatus, are made of 12 in. square timber; at the outer end a jaw somewhat like that of a vice is worked on them. The 12 in. timber has a packing piece of 2 in. thick on each side of it, and outside of these are the pieces forming the jaw 12 in. by 4 in. The flange of the main ribs being 16 in. wide, these packing pieces are fitted so that when the jaw pieces are screwed up they hold the rib firmly in its place. The 12 in. square piece is bolted firmly down by four $1\frac{1}{4}$ in. bolts. These bolts do not pass through the slides, which are made so as to be capable of adjustment: a cross piece is placed on the top of the slide, the bolts pass through this and outside the slide, but touching it; a cross piece is also placed under the walings or platform timbers and the whole bolted down. Two of such bolts and cross pieces are fixed at each end of the slide. It is forced outwards by the folding wedges which abut against the main vertical timbers.

Details.

The side or wing stage (marked the *west* wing), is in all respects a complete working model of the stage actually, the cast iron caps for joining the verticals are made of brass. The boxes for receiving the ends of the verticals are also shewn in brass.*

In the centre compartment and east wing of the model the timbers are not spliced but run through from top to bottom, being tapered to the correct scantling at each part of the stage.

Hoisting Jibs or Derricks.

The hoisting was in all cases done by derricks which were capable of being swung round. The steam crab for hoisting was on the floor of the station, and all the ropes from the derricks were led to it by snatch and fairlead blocks; four of these derricks were constantly in use, two at each side of the stage. They are made of timber, the section octagon 10 in. over the flats. The head of the derrick is fitted with the usual swivel apparatus, the foot is fitted with a regular ball and socket joint, with a gland and screws, in order to prevent the foot from being jerked out of the socket in the event of the guy rods being removed and the jib allowed to drop on to the staging. In hoisting the segments of the ribs, these derricks had of course to project clear over the side and end of the staging. When the segment had got to the proper height, it was swung round to its place.

When not in use for hoisting, or when the staging was passing from one main rib to another, the guy rods were removed and they were lowered on to the platform.

Steam Crab.

The steam crab for hoisting was made on purpose for this work by Messrs. Appleby Brothers, and was specified to suit the other parts of the apparatus. It has two barrels: two permanent ropes can be wound on it at once, the end of the shafts which carry the barrels are prolonged outside the framing, and carry a pair of warping barrels, both were worked in the same direction, and the rope wound half round each three or four times, by this system there is no surging of the rope and it can be removed in a moment. As I have said, all the ropes from the staging led t› this crab, they were thrown off and on, and coiled away in a manner that was very satisfactory.

General.

Having gone through the whole of the apparatus in detail, I have now only to describe in a few words the mode in which it was actually used. I may here perhaps be allowed to express my thanks

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* These are references to a working model of the staging which was exhibited at the Institute when the Paper was read.

to Mr. John Clarke, the foreman, to whose care the use of this great heavy machine and the erection of the floor and roof was entrusted, for the skilful and energetic way in which the work was executed.

The method adopted in putting up the main ribs, purlins and intermediate ribs was this:—

It was ordered that the box girders and plated part of the main ribs should be erected first on baulks of timber, and after being wedged up to the proper position should then be *under built*. The same system was adopted for the intermediate ribs: they were hoisted to their proper position, wedged up with timber, and under built.

I had therefore not only to depend on the staging for hoisting and keeping the whole of the roof in the proper shape, but also to impose on it the duty of providing lateral support for the whole structure. No support could be got from the walls until the walls were up, and the wind ties fastened to them. The design of the roof generally is bold and excellent, the ribs are self supporting from the very floor, the side walls have only to carry the ends of the intermediate ribs and the wind ties. Until these side walls, however, were built and the wind ties fastened to them, the stability of the whole (laterally) was secured by the staging. The support was obtained as it passed from one station to another, never leaving its hold until the last rib had been fixed.

The mode of commencing the work was this:—

The first and second box girders and plated part of the main ribs to be erected being fixed, the whole stage was brought with its timber slides opposite to this part. A centre line was marked on the plated part, and a centre line set out with a theodolite on the stage itself, to indicate the exact position of the centre of the main rib. The whole staging of course was bolted firmly together and also bolted to the floor.

The timber slides were then carefully adjusted, their centre lines coinciding with that set out by the theodolite. The slides were so adjusted as to keep the rib to a larger curve than it would represent when finished, because it was necessary to keep the segments out or open to allow the last segment to be got into its place. This being done, the temporary screws were withdrawn, the slides were drawn a little inwards to allow the joints to come together, and the riveting began. Two ribs were thus being fixed together, but only the two first ribs; the purlins and intermediate ribs were also fixed and riveted up. When all was complete, the timber slides were slacked a little, and the ribs were allowed to take a portion of their own weight.

The staging was now ready to move; the wedges of the wings were knocked out; the holding-down bolts on the sides of these wings slacked, and the slides drawn entirely inwards; the bolts and chocks which held the wings to the floor and to the centre compartment were removed; the centre compartment was kept screwed fast to the floor, and the slides were also kept fast. The wings were then removed until their leading slides were in line with the third rib—the centre compartment all the while holding fast to both ribs. When the wings had been moved to their proper position they were screwed down to the floor; by their slides they held fast to No. 2 rib, the slides being forced well outwards, and carefully fixed sideways. The slides of the centre compartment were then drawn in; it was drawn up nto line with the wings; the whole was screwed fast as before, and all the three compartments took hold of No. 2 rib, No. 1 being supported laterally by its purlins, which were riveted to No. 2; but carrying its own weight as well as that of half the purlins and intermediate ribs. When No. 3 rib was fixed and finished, the same operation was repeated for No. 4 rib, and all the others to the end of the station, the stage never leaving its hold until all was completed.

Professor Kerr, Fellow.—There are one or two particulars of details which perhaps the author might be kind enough to supply, viz., first, what is the weight of the entire structure? Secondly, what is the cost? and thirdly, what time was occupied in its removal from one part to another?

Sir JOHN G. N. ALLEYNE.—I think the cost was between £3,000. and £4,000. The weight of the whole staging was about 600 tons; and the time occupied in moving each portion of the structure was about four hours. When it got fairly into working it was done in somewhat less time. The cost of moving was about £18. each time.

PROFESSOR KERR.—I now beg to propose a vote of thanks to Sir John Alleyne for his kindness in coming forward at the request of the Council to read a paper on this certainly most ingenious piece of construction. It is a subject on which I am not able to make any remarks by way of criticism, or to contribute anything towards the enlightenment of the meeting in any respect, in which it might desire to be enlightened, but I am quite sure we shall all agree at the outset of the discussion that it is a most meritorious work and that the designer of it, in our judgment of such things, is a most meritorious man. The figures he has been kind enough to give us in answer to my questions afford to us probably a more intelligible impression of the whole case than some of the details which have been described so elaborately, and the feeling in the mind of the meeting at large must, I think, be like my own, and considering the vastness of the structure, the greatness of its weight, the short time involved in moving it, and the apparently extremely moderate cost at which it was constructed and moved, everybody must agree that these considerations contribute to enhance our appreciation of the great merit of the work. I beg to move that the meeting give its best thanks to Sir John Alleyne for the description of his work, which he has laid before us.

Mr. COCKERELL.—What was the nature of the platform on which the staging moved?

Sir JOHN G. N. ALLEYNE.—It was the floor of the station itself, viz.: lines of columns, on which there were lines of girders and cross girders right across the station. There were three lines of columns and girders for each two ribs. There were girders and cross girders, and Mallet's buckled plates. The floor was perfectly rigid, and was thus protected from being punished by the weight. I put the number of wheels mentioned under the staging to avoid any question of over-straining the floor. There was about 5 tons to 5½ tons on each wheel, this being considerably less than the weight on the wheels of a locomotive engine. I found that the wheels moved perfectly well. Mr. Clarke used a gong, one of the buckled plates, to direct the movements of the men. At the side staging there were 24 men at the wheels, each with a pinch-bar, and when the gong was struck, each man pinched about 2 inches. It was almost like rowing a boat. On some occasions the men worked to the time of a tune.

Mr. T. MORRIS.—The method just described for giving the utmost force to workmens' efforts brings to mind those employed at Rome in raising an obelisk, which had lain for centuries embedded in the dust, in fact, from the overthrow of the Roman Empire till the 16th century. It was then determined to erect that obelisk, but to raise so large a stone put them to their wit's end. They got up a competition and received designs, and to give effect to the operations of the workmen at the levers, capstans, &c., they employed, as Sir John Alleyne had explained in this case, instruments of music, that the men might know when to exert themselves and when to halt. I have not met with any instance of the sort till now in modern works. The structure exhibited in the model is certainly one of the most stupendous of the kind that has ever been put together, and it shows a wonderful advance of mechanical science in this age over previous times. At no very remote period from the present time it would have been perfectly impossible to construct a moveable apparatus of this nature.

I recollect that many years ago I went into the Museum at Boulogne and saw the model of the scaffolding by which the First Napoleon had the column erected at that town. It was almost solid, so surprisingly numerous were the poles of timber employed. Shortly after the period of that visit the project of the Nelson Column was set on foot, and this kind of whole timber scaffolding shown in the model before us was brought into action. Mr. Allen, foreman to Messrs. Grissell and Peto, a man of

great practical knowledge of mechanics, took a great share in it. But the scaffoldidg for the Nelson, Column was a mere bird's nest compared with a construction of this kind. I do not call it *framing*, because I am not sure it would be right. I do not think the timbers are framed. It is a construction but perhaps Sir John Alleyne will be good enough to explain how the timbers are connected and coupled together. In the case of the Nelson Column a circumstance occurred which tended to make the scaffolding a very economical affair, inasmuch as a gentleman who was about to build a mansion in Leicestershire gave an increased price for the timber of that scaffold because it was more thoroughly wind seasoned than any other timber that could be got. I beg to add my humble testimony to the great skill which is displayed in the work before us, and to the pleasure which the description of it must have afforded to those who are interested in the subject.

Mr. Edward Hall, F.S.A., Visitor.—Perhaps it may interest gentlemen to be reminded of a failure which took place in the case of a very important scaffold, viz. the trussed staging adopted for the construction of the roof over the centre transept of the Crystal Palace, at Sydenham. A great deal is to be learnt from failures. The paper read here some time ago by Mr. Nash, on Cases of Failure in Construction, elicited a most valuable discussion, and I think it would be desirable if frequent attention were paid to such instances. As regards the accident at Sydenham, it had been attempted to avoid the enormous expense of scaffolding raised from the ground; and a novel system of truss was adopted, somewhat analagous to ordinary diagonal bracing in form, or rather to the Warren girder, but with some important modifications affecting the principle of the construction, including what seem to have been serious defects at the junctions of the different members of the framing, where there were "shoes." In *The Builder*, of the year 1853, you will find a sketch, which I made at too great a height from the ground to be comfortable to myself, but the principle of construction is accurately shown. The whole system of that trussing may be divided into two heights, viz. a lower truss, with the diagonals,—that is to say, some of those members in compression and some in tension,—and a similar truss above that; but if you confine your attention to the lower truss, you will understand the system adopted, the upper one being, as to its main features, a repetition of the lower. Each strut or brace of the several diagonals was what was called boat-shaped; it had the exact form of a *vesica piscis;* or the only difference between the diagonals in a state of compression, and those in a state of tension, was that the former were strengthened by boarding, which concealed the bolts that kept the curved members of the strut apart. The lower member of the whole truss was a bar of wrought iron. Now, in an ordinary truss, whether of a queen-post roof, or the instance of a girder with diagonal bracing, the upper horizontal member would have been perfectly rigid. The lower member in this case was supposed to be rigid, and subjected only to a tensile strain; but according to the theory I formed, that lower member was subject to a strain of torsion, and consequently that might have had something to do with the failure. At the inquest some eminent men gave evidence, amongst them Mr. Vignoles, but not one had any theory as to the cause of the accident. My own theory was that the failure occurred at the shoes, or the parts where the diagonals in compression and those in tension were joined to the horizontal members, the tie-bar at the foot, and the jointed collar at the top of the truss. The failure might have originated from more than one defect. The tie-bar was, in my opinion, subject to a twisting strain, by reason of the planking of gangways, which were placed resting upon the tie-bars of adjacent principals; and the workmen, passing backwards and forwards, shook the whole framing, and eventually brought down the greater portion of it, entailing loss of life. Subsequently to the failure, that system being abandoned in deference to public opinion, or in order that a repetition of the accident might not occur, the plan of building a scaffold from the ground was adopted at Sydenham, and the entire transept-roof, with the exception of one or two ribs that had been erected, was constructed with scaffolding resting on the ground. Since that I believe no attempt

of the same kind has been made; though, of course, it should be recollected that many important bridges have been built without centering or scaffolding carried from the ground. The trussed girder of a bridge may be projected from the abutment on the land, till the end rests on the next abutment or pier, but I think that for the construction of all important roofs of great span, since the accident at Sydenham, the system has been adopted, which has been brought to perfection in this case of the St. Pancras roof, of working from a scaffold, or a travelling-stage, built up from and resting upon the ground, or on a broad, level and stable floor-base.

Sir JOHN G. N. ALLEYNE, in reply to a question as to how the carpentry of the tie was formed, said—It is not altogether carpentry. There is a mixture of iron and wood work. Where the diagonals join with the verticals at the point where the walings intersect, you will find that the strain arising upon them, is carried in cast-iron boxes, as is shown in the drawing on the wall and by the model. The strains are self-contained in each point and are carried and transmitted with the weight. The lateral and twisting strains are borne by the cast iron. [Mr. PAYNE asked what the set of the structure was.] I think Mr. Barlow made it out 7-16ths to half an inch, but from the construction of the staging he could not get it very accurately, because when we moved the side staging the weight of the roof of course would come more upon the centre compartment, and the haunches of the arch would spring outwards, so that a portion of the deflection was taken at the time we drew in the wedges from the side staging; but the opinion Mr. Barlow arrived at was, that the amount of deflection was 7-16ths of an inch.

In conclusion, Sir John G. N. Alleyne kindly offered to furnish copies of any portions of the drawing that might be desired. He explained that they were the property of the Butterley Company, but he was quite sure that they would endorse his promise, and that the Institute would be perfectly welcome to them.

The vote of thanks having been seconded by Mr. DAWSON,

The CHAIRMAN, in putting the motion, fully endorsed all that had been said in praise of this practical, able, and interesting paper, and expressed his appreciation of Sir John Alleyne's kind offer to furnish copies of the drawings, which, he said, would enable members of the Institute, when they came to read the paper, better to understand what had been described.

The motion having been unanimously passed,

Sir JOHN G. N. ALLEYNE said—I am sure you are heartily welcome to anything I have done. It is most agreeable to us mechanics to have the attention of such a Society as this when we describe our modes of construction. That you appreciate the work is a sufficient reward. I required no further acknowledgement. Indeed, the obligation is rather on my side, and I thank you cordially for the interest which you have shown on this occasion.

The meeting then adjourned.

SUPPLEMENTARY DESCRIPTION OF AUTOGRAPH DRAWINGS OF THE GREAT MASTERS IN ARCHITECTURE PRESERVED IN PUBLIC LIBRARIES IN ITALY.

By Professor DONALDSON, Past-President, Ph. D.

BEING lately in Italy, I was anxious to avail myself of the opportunity to ascertain the drawings of distinguished architects since the middle ages, preserved in the libraries of Venice and Milan, which I had not been able to visit when I made my former report, published in the Transactions, 28 February, 1870. I beg, therefore, to submit the following memoranda made by me at *Naples* and *Milan*.

Naples. The Public Library is in the building of the Studj (or the old Museo Borbonico) now called the Museo Nazionale. The only autograph architectural drawings are contained in ten folio volumes, 17½ inches by 11 inches, attributed to Pirro Ligorio. They treat of statues, medals, buildings, costumes, ceremonies, etc., of the ancients. The text is beautifully written, apparently by some scribe, in clear characters on blue paper. The illustrations of buildings are generally drawn on white paper. The volumes are divided into one consecutive series of chapters. The three chapters 48, 49 and 50, are more specially devoted to archæological and architectural subjects, beginning with the history of the burial of the dead, from the origin of burning the corpse among the Romans after the wars of Marius and Sulla, illustrated by drawings of cinerary vases, cups, rings, altars, sarcophagi and other articles connected therewith. He gives a bird's-eye view of an antique Ustrinum, or place of cremation. Then follow drawings of the tomb of Cecilia Metella, and plans and sections of various tombs and sepulchral temples identical with those published by B. Soria from the drawings of G. B. Montano, the ruins of which peculiar and very curious sepulchres then existed in the Campagna; but which have since the sixteenth century been dismantled of their marbles and totally destroyed. There is a plan and elevation of the Mausoleum of Augustus. At the end are four drawings of the Piscina or Castel d'Aqua of Marius, and of the Porta Maggiore, and details connected with the distribution of water in Rome. These last are on blue paper, and not on white as are the other illustrations.

Besides these it does not appear, that there are any other architectural drawings preserved in this library. One or two of Pirro Ligorio's volumes relate to ancient medals with exquisite drawings of them, but not specially to architectural medals. The text evinces a large acquaintance with the literature of the Ancients, and perfect knowledge of antique usages.

Milan. I had hoped to have been successful in the Bibliotheca Ambrosiana in finding drawings of the celebrated architects of Northern Italy, but I was disappointed; although every facility was afforded me by the courtesy of the Reverend Fathers the Librarians.

There is a volume of Leonardo da Vinci, consisting chiefly of drawings of machines, and only an occasional small unimportant sketch of a building.

There is a small 4to. volume, the title of which is "Bramantis Pictoris et Architecti Studium. Bono datum ab Ingegnierio Richino Comiti Oratio Archintolano Urbis, 1660." This is rather ostentatiously kept under a glass case. It consists of sheets of drawing paper numbered 86. Some have drawings on both sides. The illustrations are very delicately delineated in thin bistre lines, indistinctly shadowed; and the proportions not very just. The subjects are generally antique tombs, temples, and triumphal arches not very accurately rendered. Page 50 gives a plan of the celebrated circular chapel at S. Pietro in Montorio, Rome. The description is attached to almost every subject, but in very difficult Italian, written in clear square characters. There is a certain rigidity in the rawing and absence of correct proportion, which indicate a juvenile hand. One sheet, No. 79, is

divided into squares 13 to the inch, a practice of late years revived by the French. Sheet 52 gives the plan and perspective elevation of a column or pier of a church, round the shaft of which is a pulpit gracefully designed in the cinque-cento style.

Some MS. observations on a loose sheet seem to indicate, that this work cannot be of Bramante d'Urbino, uncle of Raphael; but of Bartolomeo Suardi, often called Bramantino, a Milanese. From a reference in the body of the volume to Cardinal Julianus a Ruvara, who was raised to the Pontificate, and assumed the name of Julius II., it is evident that this book was prior to 1503.

There is also one folio volume, No. 419, of Disegni e pitture by Giulio Chanpi, in Cremona and Castellini, Milanese, consisting of plans, sections, and elevations of churches, hospitals, palaces, of Milan, scenery and details; as also of altars, altarpieces, windows and ceilings, freely drawn and sketched in bistre. No. 330 fol. vol. 81 disegni e pitture. At No. 34, there is a plan of the Church of Nerviano, confirmed by the approval of S. Carolo Cardinale Archivescovo di Milano. A Triumphal arch, Palace doorways in the miserable style of 1767, similar to those in the wretched work of Ruggieri of Florence, (which are so atrocious in taste as to excite the wonder, that such examples should be selected and published, instead of noble characteristic features of Florentine art like the Strozzi, Riccardi, and Rucellaj Palaces.) Plans of S^{a}. Maria del fiore at Florence, and other churches. Drawings of the Milan Cathedral and of the fine church of S. Lawrence, with a project for strengthening it: a baldachino.

Under the word "*disegni*," in the Catalogue of MSS. are mentioned 21, in which are mixed up all sorts of subjects, the architectural ones consisting of the same class, as those mentioned above, and some engravings, generally very disappointing.

The Codices Vitruviani are—

Cod. Chart. sec. XVI. . . . . B. 43. Sup.
Membr. sec. XV. . . . . A. 90. Sup.

A Bonino Membritis conscriptum—

Cod. Chart. sec. XV. . . . . A. 137. Sup.

The fifteenth century one is very clearly and beautifully written, with occasional marginal corrections. The spaces, $1\frac{1}{4}$ inch by $1\frac{1}{10}$ inch, are left plain for the large capital letters to be painted in at the commencement of each book. The headings in capital letters are coloured red, green and blue; the general colour of the ink is brown. There are no illustrations. At the end,

1474 Τέλος IO -NY.

Such are the scanty results of three mornings' study in the libraries at Naples and Milan of three or four hours each day. But it is impossible to ascertain accurately any special class of drawings without examining minutely every volume or portfolio, in each of which there is generally a great deal of rubbish.

There was originally a collection in the Ducal Palace of the family Litta at Milan, entitled "*Disegni degli Edifizj di Milano*," which was on sale when I was there; and the owner of which desired to dispose of them to the Municipio. I saw a list, which I append, but the buildings are mostly churches and of little interest. There is a list of the Architects of the drawings "Architetti de' quali esistono i disegni o se ne fa parola," which does not more precisely state, which are the names of the persons who made the drawings, or of the Architects who designed the buildings represented.

THOS. L. DONALDSON.

December, 1871.

Disegni degli Edifizj di Milano della collezione della Casa ducale Litta.

A.

S. Agostino in Porta Nuova.
S. Alessandro in P. Romano.
S. Ambrogio in P. Vicinese.
S. Angelo in P. Nuova.
S. Antonio in P. Vicinese.

B.

S. Barnaba al Fonte.
S. Barnaba, Padri Barnabiti.
S. Bartolomeo.
Brera, Università, ora Accad. di belle arti.
Broletto.

C.

Canobiana.
Canonica.
Carcere detta la Mala Stalla.
S. Carpoforo.
S. Catterina alla Ruota-Monache.
S. Catterina alla Chiusa-Monache.
Certosa di Pavia.
Collegio Elvetico-V. Palazzo di Governo.
Corte Ducale.

D.

S. Damiano alla Scala.
S. Donnino alla Marza.
Duomo.

E.

S. Eustorgio.

F.

S. Fedele.
S. Filippo Neri-Monache.
S. Francesco Grande.

G.

S. Giovanni alle Caserotte.
S. Giovanni detto alle 4 faccie.
S. Giorgio al Pozzo.
S. Giuseppe-Oratorio.
S. Grazie (Madonna delle).

L.

Lazzaretto.
Lentasio (Monache) ora Teatro.
S. Lorenzo. .

Architetti de' quali esistono i disegni, o se ne fa parola.

Alessi. Galeazzo.
Barca Pietro Antonio.
Bassi Martino.
Biffi Andrea il vecchio.
Biffi Andrea il giovine.
Binago Lorenzo.
Bombarda Gio Bătta.
Brambilla Francesco.
Campi Antonio.
Capitani Gerolamo.
Castelli Francesco.
Cesariani Cesare.
Da Gamodia Enrico.
Ferrari Frañco Bernardino.
Filarete Antonio.
Mangoni Fabio.
Meda Giuseppe.
Nuvoloni Antonio.
Pellegrini Pellegrino.
Pescina Gio Ambrogio.
Piscina Giulio Cesare.
Piermarini Giuseppe.
Polach Leopoldo.
Quadrio Gerolamo.
Ricchino Francesco il vecchio.
Ricchino Francesco il giovine.
Ricchino Gio Domenico.
Rinaldi Tolomeo.
Rossone.
Saregni Vincenzo.
Solari Cristoforo.
Trezzi Aurelio.
Tribiglia Francesco.
Zenale Bernardo.

N.B.—Ad ogni tavola di fabbricato, palazzo, monastero, ecc. stà davanti la sua relazione.

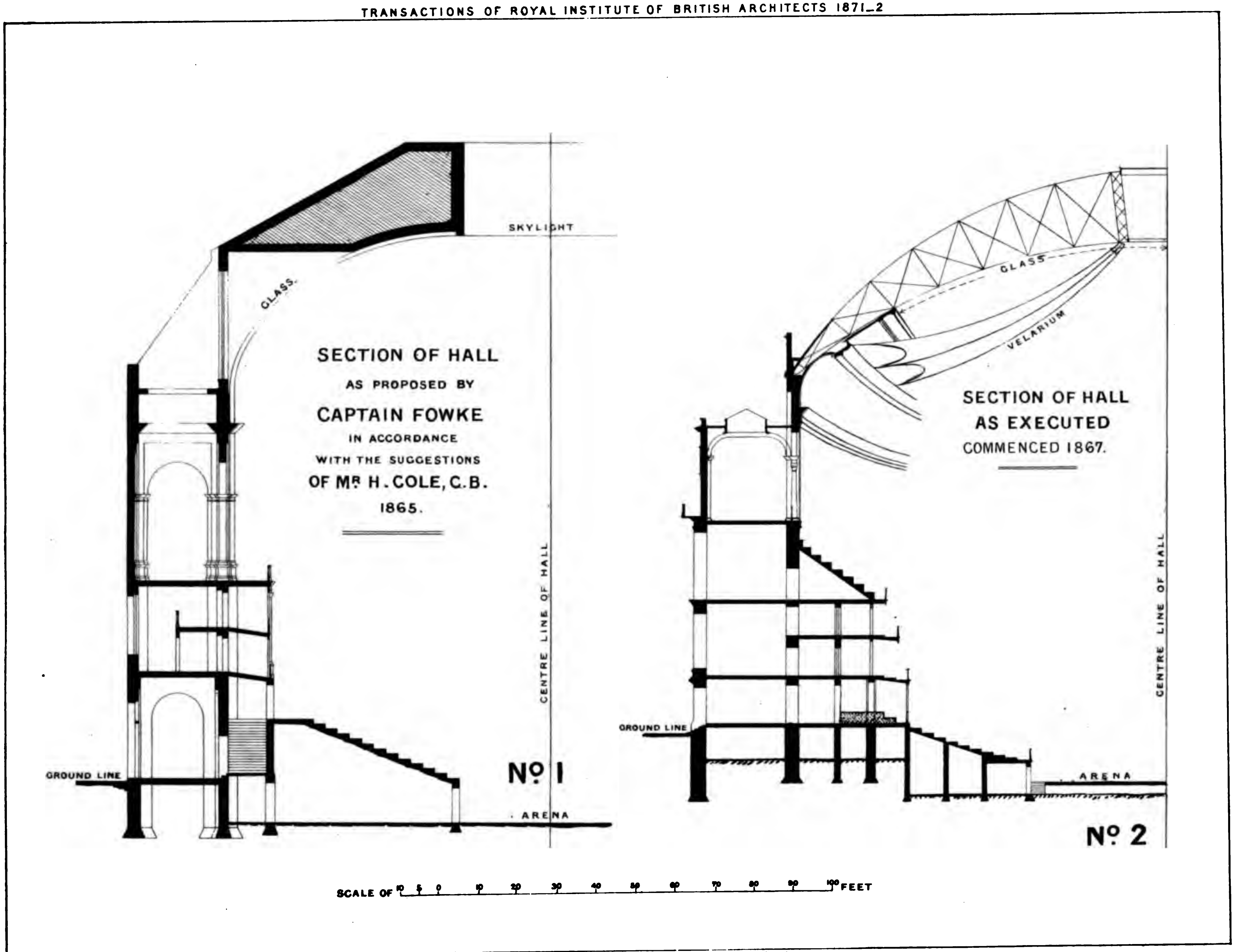
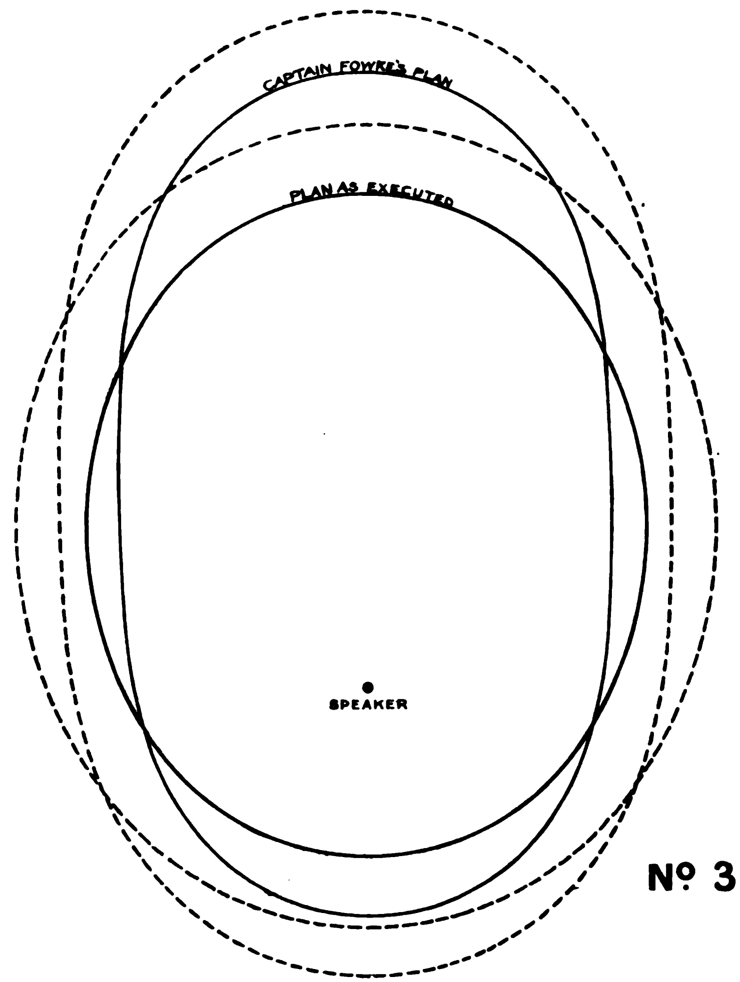


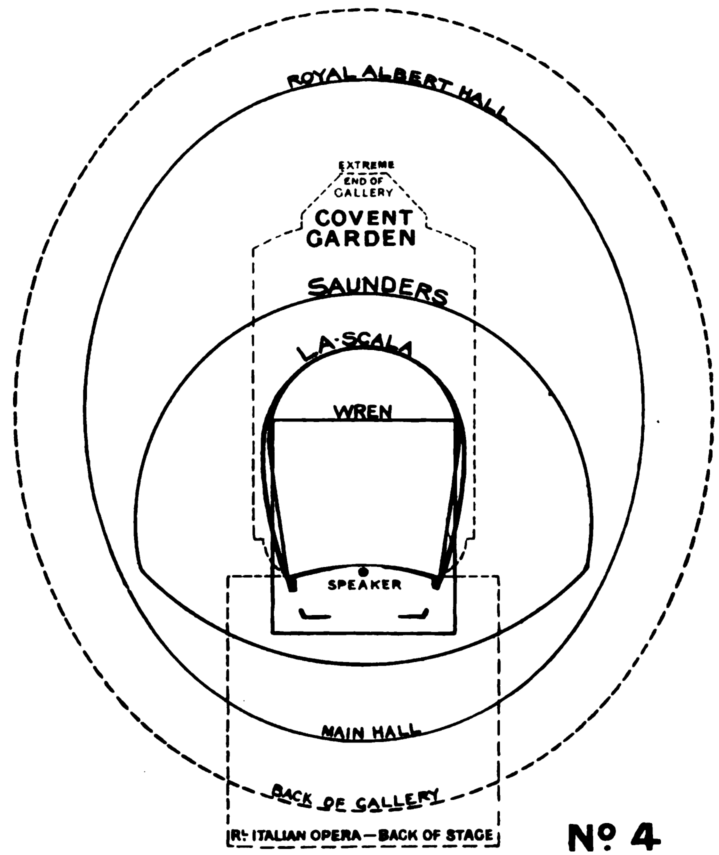
Photo-Lithoᵈ for the R.I.B.A. by Whiteman & Bass, London.

DIAGRAM TO SHOW THE SHAPE OF HALL DESIGNED BY CAPTAIN FOWKE AND OF THE HALL AS NOW EXECUTED BOTH PLANS DRAWN TO SCALE



No 3

DIAGRAM SHEWING RELATIVE SIZES OF R·A·HALL OF CHURCH GIVEN BY WREN, OF SAUNDERS'S PLAN AND TO THE THEATRES: LA·SCALA· AND COVENT GARDEN



No 4

Photo Lithod for the R.I.B.A. by Whiteman & Bass, London.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 22nd January, 1872, the following Paper was read, THOMAS HENRY WYATT, Esq., President, in the Chair:—

ON THE CONSTRUCTION OF THE ALBERT HALL.

By MAJOR-GENERAL SCOTT, C.B., &c.

ON first receiving from your Committee an invitation to read a paper on the construction of the Roya Albert Hall, I hesitated to comply with the request made to me, both on account of the numerous calls upon my time, and the reluctance I felt to appear before your distinguished body in the character of an architect, a title to which I make no pretension. On reflection, however, it appeared to me that one who had benefited by the advice of members of your society in carrying out the duties entrusted to him so largely as I had done, ought not to shrink from contributing his quota to the general stock of information on constructive difficulties and expedients, or from enabling so novel and gigantic an experiment as the Albert Hall to be freely criticised for the benefit of others who may hereafter be called upon to plan and execute buildings of like kind.

On considering what might be expected from me, it appeared to me that a complete descriptive memoir of the work would be more than could be read within the limits of time prescribed, and that my best course would be to select such points of it as exhibited some novelty in practice, or involved some important principle which might be elucidated by discussion. Before, however, entering upon my subject, it is necessary that I should premise a few words on the conditions which were imposed upon me in carrying out a work, the general conception of which as to size and arrangement, was originated by others. It is a task of some delicacy under such circumstances to avoid on the one hand charges of self laudation and depreciation of the original design, and on the other hand to avoid exhibiting a too morbid desire to escape such imputations and reference to questions, the free discussion of which should be the object of your meetings.

In this difficulty I have thought it best to place before you the drawings and model of the building as designed by the late Captain Fowke. This model was completed in Jan., 1865. These were put in my hands as the basis of the design that was to be executed, and without hesitation, and in the reliance that you will interpret my motives generously, I invite attention to the modifications I have ventured to make, and to my reasons for considering them improvements. It is, however, necessary that I should make it clearly understood that the model and drawings exhibited to you as Captain Fowke's, embodied only his first rough ideas on the subject, and that what the building might have become if he had lived to mature his design cannot be fairly judged of from them. The model of the interior and the exterior elevation are so little in accord, indeed, that they cannot be said even to belong to the same structure. That this was so, naturally left to me the greater latitude in re-modelling his work, but of his latitude I always hesitated to avail myself until I found that my opinions were fortified by the approval of others. For such reluctance to make changes I claim no praise. It is simply due to the fact that whilst I have always considered that my late brother officer and friend was naturally gifted with unusual architectural and constructive ability, I have not had equal confidence in my own. I have

only to add to this introductory explanation, that the original notion of such a hall was the offspring of the fertile brain of Mr. Henry Cole. Diagram 1 is an enlargement of a pen sketch by him which was sent from Amiens, 8th Nov., 1863, to Mr. Gilbert Redgrave as the first idea of the section of a building to seat 17,000 persons.

The data prescribed for my guidance were these:—

1. That the building should be of amphitheatrical form, and should seat in ease and comfort 6000 or 7000 persons.
2. That the interior accommodation for an audience should consist of:—
   (*a*) An arena which might occasionally be used for a promenade or exhibition.
   (*b*) Some ten or twelve rows of seats above the arena arranged in the form of an amphitheatre.
   (*c*) Two or three tiers of boxes above the amphitheatre seats.
   (*d*) A great gallery open to the interior of the hall, running round the building between the interior and exterior walls, and top lighted.
3. That the entrances and exits should be arranged like the seats on the plan of the old Roman amphitheatre.
4. That the façade should be of red brick and terra cotta dressings.
5. That the whole expense of the work should not exceed for building works and expenses connected therewith, £175,000.

With these instructions, I found myself in the possession of an advantage such as probably no architect ever yet enjoyed, or probably would care to enjoy. I was to have the advice of a committee, and this committee consisted of the following eminent architects, artists, and engineers, viz:—Sir Wm. Tite, Sir M. Digby Wyatt, and Messrs. Fergusson, Fowler, Hawkshaw, and R. Redgrave, R.A. I take this opportunity of publicly thanking these gentlemen for the valuable assistance they rendered me. Whilst they showed not the slightest desire to do my work for me, they were ever ready, collectively and individually, to help me to do it myself.

At a preliminary meeting of the Committee a question was raised on the first of the above data, which it is to be hoped will be fully discussed this evening. It was suggested that instead of the form of the Roman Amphitheatre, that of the Greek Theatre should have been taken as the model. The general form of the amphitheatre was, however, considered to be one of the fixed conditions of the problem, but it is a fair question for debate whether the results give reason to suppose that any other shape would have enabled an audience better to hear varied musical performances, or have afforded a more imposing effect. The general form proposed by Captain Fowke for the plan of his interior had semi-circular ends, joined by almost parallel sides, as shewn in diagram 3. The plan executed, shown in the same diagram, is a very close approximation to an ellipse, and is formed of arcs of circles struck from four centres. By this means the difficulties in construction which the varying curvature of the ellipse would have entailed, have been avoided. The major and the minor axes between the walls which carry the roof, are as 11 and 9 nearly. This form was determined on after careful consideration of the following experiments, opinions, and facts.

The experiments of Saunders, described in his well known work on Theatres, showed that a person reading from a book could be equally well heard in the still open air at a distance of 92 feet in front, 75 feet on each side, and 31 feet behind. Sir C. Wren's distances for the same position with reference to a speaker having a good delivery, are for an enclosed building, 50 feet, 30 feet, and 20 feet. The distances proposed by Captain Fowke were 204, 82 and 76 feet, and in the Scala Theatre at Milan, the largest and the most perfect lyric theatre existing, the distance from the curtain to the back of the boxes in front is 105 feet, and the greatest half width of the auditorium 43½ feet.

It will be observed that the distances for equally clear hearing in the open air are according to Saunders as 5, 4.5, and 2, for a person standing in front of, at the side of, and behind the speaker, whilst Wren estimates the same distances in an enclosed building to be in the proportion of 5, 3, and 2 ; Captain Fowke apparently attributed much more influence than Wren to the effect of side walls in carrying the wave of sound forward, for his distances are as the numbers 5, 2 and 1.8. The distances actually adopted in the case of the hall are 163 feet in front, 92½ feet for the half width at the broadest part, and 56 feet behind the position of a solo singer. These distances are very nearly in the proportion of 5, 3, and 2, the proportions given by Wren. Including the width of the picture gallery, the distances from the singer in front is 186 feet, and the half width 116 feet.

The plan of the hall is shown in diagrams 3 and 4, in juxtaposition with the forms which would have been given on the four above-mentioned conditions, and this in connection with diagrams 1 and 2 enables the modification of Captain Fowke's plan, both as respects size and shape, to be estimated. The main grounds on which this modification was made are sufficiently apparent, but the alteration also afforded the opportunity, owing to the greater width given to the building, of introducing the balcony, which was not a feature of Captain Fowke's design, and which provided accomodation for 2000 seats of a cheaper description, with a sacrifice of 800 seats in the amphitheatre and arena. The increased curvature of the sides also had collateral advantages as respects the stability of the roof, and my Committee of advice agreed to the advisability of making the change on general, if not on architectural grounds. Although, from certain points of view, something of the grandeur of Captn. Fowke's proposed arcade may have been sacrificed, more than the equivalent of this loss has been, to my own mind, gained by giving to the arcade a visibly solid wall to stand on from whatever part of the interior it might be seen. A reference to diagrams 1 and 2, which contrast the two sections, will enable this question to be judged of. The total length from outer wall to outer wall as executed, is 266 feet, and the breadth 232 feet. With reference to the general shape of the interior, I have only to add that the length, breadth, and height do not materially differ from the proportion 5, 4, and 3, though this would scarcely be judged to be the case from the appearance of the building. The actual figures are a length of 219 feet, a breadth of 185 feet, and a height of 136 feet. I have generally found that the height has been much over-estimated by visitors. This is probably due to the contraction of the floor by the amphitheatre arrangement of the seats. The central portion of the ceiling in the original model was flat, as may be seen. The plan adopted of following the arched form of the lower members of the ribs of the roof with the glazing was simpler, and though it appeared to threaten greater danger of echo than a flat roof, from the concentration which it would give to reflex waves of sound on focal points of the auditorium, it afforded a better opportunity for introducing a velarium, which, whilst it acted as a sunscreen, imparted to return waves that divergence which was manifestly to be desired.

It has been assumed by some critics of the acoustics of the Hall that the velarium was an invention introduced to cover a defect found out only by experience. But its expediency, with the reasons for and against it, was as freely discussed in the architectural papers in the beginning of 1869, when the roof was not yet fixed. As early as December 12th, 1868, the "Standard" speaks of it, and on April 26th, 1869, the "Globe" informs its readers that "underneath the dome it is proposed to suspend a velarium, to act as a sunshade, and to deaden or prevent the reverberation and echo." It was indeed too natural an idea that a building so resembling a Roman amphitheatre should be covered with a velarium, to allow the question to be overlooked. This plan of obtaining a satisfactory ceiling was mentioned to me at a very early period by Sir W. Tite, but it is really to Mr. James Wild that I am indebted for urging upon me that it was the only appropriate way of covering the building, until—adverse criticism notwithstanding—I determined on adopting it. Mr. Wild's idea, however,

was that there should be no coving, and that the velarium should be attached to the vertical walls of the structure, forming in fact the entire ceiling underneath the double glazing, but it was thought that it would be impossible to give through the scallops of the velarium (owing to the forest of iron ribs, purlins, and ties of the roof), anything like the effect of the sky which one might expect to see, and there was a fear that something more substantial than a mere covering of cloth underneath the glazing would be necessary in this country to impart an idea of security and comfort. Mr. Wild's proposition would moreover have rendered the lighting by gas more difficult, and by the omission of the coving have deprived the auditory in the balcony of a sounding board, from the proximity of which a strengthening of the sound waves was expected.

I may remark in passing that a great collateral advantage in point of artificial lighting is gained from the white reflecting surface of the velarium. Large quantities of light are absorbed at night by a dark glass roof.

In considering the mode in which the interior of the walls of the Hall should be finished, three courses were open, each of which had advocates whose opinions merited consideration. The first course was to discard resonant materials as far as possible. Those who think that this is the right course argue that after the sound has reached the ear by direct radiation, the sooner it is absorbed the better, and that any degree of resonance from the walls is detrimental to musical effect. A second course was to finish the walls with hard well polished plaster, and to lay the floors with tiles. This was the opinion of Mr. Willis, who built the organ, and whose voice in the matter necessarily demanded attention. A third course was to line the walls with a resonant material, and wood was determined on for the following reasons.

1. It was believed that sound in its utmost purity is heard in still open air, and that this may be due not only to freedom from disturbing reflections, but also to the absence of causes interfering with its free transmission, and checking vibrations isochronous with the vibrations of the atmosphere, such as would be interposed by draping the walls.

2. It had been noticed that tiled floors gave rise to sharp, irritating reflections of sound, such as may be perceived in the centre refreshment room of the South Kensington Museum.

3. The buildings most remarkable for their acoustic properties have all been lined with wood. The celebrated Theatre of Parma in which a speaker could be heard when speaking in a low tone of voice at a distance of 140 feet, Her Majesty's Theatre in the Haymarket which was destroyed by fire, the Surrey Music Hall which shared a similar fate, and the Theatre of the Royal Institution, all especially successful buildings in point of sound, were lined in this manner.

4. It is a generally received opinion that a room sufficiently non-resonant for a speaker with ordinary rapidity of utterance, and without modulation of the voice, is too dead for musical purposes, which were to be the chief purposes of the Hall, and the resonance from wood is universally admitted to be more beautiful than that obtained from any other material.

5. The correction of undue resonance is easily accomplished by draping, but it would be costly to impart resonance to a building deficient in this respect.

Acting on these considerations, and the results of my many conversations on this subject with Mr. Roger Smith, whose information on matters of acoustics was always at my service, the whole of the high wall behind the orchestra was covered with ½-inch battens carefully tongued together with an air space of ¾-inch between this wood lining and the wall. The whole of the wall of the picture gallery, with the exception of the pilasters, which divide the wall into bays, was lined in a similar manner. The coving of the roof, with the exception of the cornice which is of fibrous plaster, and that portion of it which is not of glass is also of ½-inch battens tongued together, and covered on the upper side with canvas

stretched and glued upon it. I attribute the fact that the most delicate musical sounds are distinctly audible, even at a distance of 186 ft. from the performer, to be due, in no small degree, to the existence (near the most distant listeners) of the wooden sound-boards with which the Hall is lined. There is one other point in the acoustics of a building of this immense size to which I should wish to draw attention. Loud noises must produce a distinct return sound, though it may be a slight one, from distant walls however covered. If any one of my hearers will, on the next still day he finds himself in one of our parks, clap his hands, even with leafless trees in front of him, he will obtain an echo, the audibility of which, if he has not performed the experiment before, will surprisehim ; or if when on one side of a valley, although the slope opposite to him has no great inclination, he will make a sudden noise, he will obtain a reflex sound, the intensity of which will also be very considerable. If, again, in the neighbourhood of two buildings at different distances from him and in different directions, but exposing surfaces towards him capable of returning distinct echoes, he will listen for the echo from one building, he will hear this only, and then on listening for that from the other he will hear that one only, and yet by an effort of attention, he will be able to succeed in hearing both distinctly return the sound he makes. And, lastly, if, as I have done, he walks about making experiments and listening for echoes, he will raise a ghost which he will find it very difficult to lay. The ear, in fact, becomes painfully susceptible of impressions of this description, and listening for echoes had much to do with those which were once complained of in the Albert Hall. We now no longer hear of them, because people go to listen to the music and not for reflex sounds, which, doubtless, so far as they are appreciable, injure it. I am not of course speaking of such distinct echo from the roof as was heard in the arena from the Prince of Wales' voice on the opening day. This was occasioned by the reflection of the waves of sound from the convex glass roof, which the velarium was too thin to intercept, and which has been remedied by calendering and filling up the pores of the cloth of which the velarium consists. I speak of the reflex sound which, as I assert, must be returned audibly enough to be heard, if listened for, from distant surfaces even if clothed with persons, when the loudest percussion notes of an orchestral performance occur. This is an inherent defect, so far as it goes, of very large buildings. On the other hand, it is not unreasonable to suppose that delicate passages of music are heard in greater purity in very large than in small rooms. The removal of the disturbing surfaces to a distance from the source of sound may render reflections from them inappreciable.

There is one other point in connection with the acoustics of the building which I think is worthy the attention of architects. It is a matter of common observation that musical sounds often set up a vibration in the sound-board of a piano, glass drinking vessels, and similar resonant objects. Manifestly an interval must elapse between the actuating sound and the sympathetic response, and if the wooden coving of the Hall or the lining of the picture gallery respond to Sir Michael Costa's big drums or the loudest notes of his trumpets, we should from this cause, also, obtain in some positions, an echo-like repetition of the original sound at an appreciable interval. It is an interesting question how far the effects of the loudest musical passages have, by the resonance of the lining of the Hall, been sacrificed in obtaining excellencies as respects those of greater delicacy, for which it was predicted that the Hall would fail.

An important modification of the original design has been made in the arrangement of the staircases. It was originally intended that the space between the inner and the outer wall should be completely filled with stairs and landings, the one over the other, running spirally round the building and all having their exit in one common corridor. Instead of this, a plan has been adopted which gives to each staircase, or pair of staircases, an exit into a separate crush room, thus enabling visitors in different parts of the building to be kept separate. Arrangements can also be made in some cases for using

particular stairs for one or the other part of the building, but assuming the normal occupation of the different parts by a very full house and the ordinary appropriation of the staircases, the provision made is at the rate of one staircase to 200 persons for the boxes and arena, and one staircase for 500 persons in the balcony and picture gallery. The amphitheatre has one exit for every 250 persons. Each of these exits is 9 ft. wide. Sixteen of the staircases are 6 ft. 6 in. wide and two of them 4 ft. 6 in. wide. There is also a lift which can convey about 15 persons at a time to any of the floors but the basement, and a space left for a second lift of equal capacity. The lift is worked by hydraulic pressure, and was executed by Messrs. Easton and Amos. The corridors, crush rooms, and staircases, together afford sufficient space for the whole of the visitors which the auditorium and orchestra will contain, to be in movement at once without jostling each other. The result of this ample provision of corridors and staircases is that the auditorium empties itself in a few minutes. Full advantage, however, of the numerous exits of the building cannot at present be made available to nearly the full extent of which they are capable, but it is in contemplation to make roads both to Exhibition and Albert Roads from the south-eastern and south-western sides of the Hall, and a Bill will be introduced this Session for connecting the Hall with the South Kensington Station by Pneumatic Railway. The Hall at the present moment provides accommodation for the following numbers in its different parts :—

In the orchestra	1000 singers.
,, ,, ...	200 instrumentalists.
Arena	810
Amphitheatre and Loggias . .	1642
Boxes	830
Balcony	1783
Organ Gallery	100
Picture Gallery	2000
Total	8,365 persons.

By putting the seats in the arena closer together, and by filling the gallery with raised seats, this number could be increased to 10,000 persons, a formidable number to provide for, in these days of cabs and carriages, whatever be the facilities for entrance and departure. The sum of the widths of the external doors for these 8,365 persons is divided between twenty-five entrances, of which that from the Horticultural Conservatory is 16 ft. wide and all the others 4 ft. 6 in. wide, being one foot to every sixty-four persons.

Before leaving those parts of the arrangements which have reference to the accommodation of an audience, I should mention that the allowance for each amphitheatre seat is 3 ft. by 2 ft., the chairs turning on an axis both to allow greater freedom of passage for reaching the inside places, and to enable persons on the sides of the building to turn towards the singer. In the balcony the allowance is 2 ft. 6 in. by 1 ft. 8 in., and room for passage is afforded by the seats turning up and allowing their occupiers to stand between their supports. In the arena, boxes, and gallery the seats are not fixed and can be changed according to the requirements of the entertainment. It will be observed that the part of the two upper tiers of boxes which is supposed to be occupied by persons listening to a performance, projects some distance beyond the compartments above them. This arrangement was made with the idea of bringing their occupants more into view, and thus adding to the imposing effect which is given by a great number of well dressed ladies.

The roof is perhaps the most interesting of the constructive features of the building, In its first conception I had the advantage of the counsels of Messrs. Fowler and Hawkshaw, who were members of

the committee of advice, and I was also assisted by the engineering ability of Messrs. Grover and Ordish, to whom were entrusted the preparation of all the drawings as well as of the calculation of the strains on which they were based.

It would be impossible on this occasion to give to this subject the attention which it merits, and I must confine myself to a reference to the general principles and considerations on which reliance was placed for the security of the structure. It is well known that disaster was prophesied here as well as in those acoustic properties of the Hall which have proved its greatest success, and in each case, even in the absence of such prognostications of failure, there was enough in the gigantic nature and novelty of the undertaking to cause some anxiety.

In the diagram on the wall you will see the first rough notion of the roof, which was left to me by my predecessor. As you will observe, it was supported by buttresses resting on the two walls of the building; but to have taken advantage of this means of receiving thrust it would have been necessary to have accepted an unequal division of the bays of the outer wall, as shown in Captain Fowke's elevation, for it is manifest that if the columns supporting the roof in the interior of a structure are arranged on an ellipse, the prolongation of radii through these columns to an outer wall will not equally divide this wall if it be an ellipse parallel to the first one. Some other means than buttresses, therefore, had to be devised for securing the wall which carries the roof against its thrust. The expedient adopted for this purpose was a wrought iron wall plate of girder shape resting with its web on the wall and supporting the ends of the roof principals. At the first blush there might appear to be danger in trusting to the varying rates of expansion of brickwork and wrought iron in a continuous girder of nearly 700 ft. in length, but it was considered that even if the expansion of the iron caused an irresistible strain on the brick arches which joined the piers for supporting the roof, the elasticity of the piers would be sufficient to take up the expansion of the wall plate, and no further damage could result than minute and probably invisible fractures, through the crowns of the arches. As a matter of fact, we thought that in one arch we did detect a fracture on the inside, but could not trace it on the outside. The clerk of the works thought that he had detected fractures in three other arches, but he was unable again to find them to point them out to others.

The next question was how far a girder wall plate of reasonable weight could be trusted to take the thrust of the roof load and the strains arising from wind. Of course, if the plan of the building had been circular, the strain on the wall plate, independently of strains from wind, would have been equal at all points, but with an elliptical plan the thrust of the principals of the roof, owing to the inequality of the weight of roof upon them, would vary with the inequality of the two axes of the ellipse. Nevertheless, Mr. Hawkshaw counselled the adoption of simple ribs having one member only, but of considerable strength, which should carry a central curb rising and falling freely with the variations of temperature. The simplicity of this idea had much to commend it, but I was too timid to adopt it, and principals like those at the Cannon Street Station, on the trussed girder system, were determined on. The lower member, however, instead of being a simple tie-rod of circular section is made of an inverted T form to enable it to receive compression as well as take tension. By uniting, also, both the upper and lower members of these principals in central curbs, which are assisted in keeping their form by tie-rods, the principals are enabled to act either as arches or trussed girders, and thus can better cope with unusual or irregular strains.

In considering the probable stability of such an arrangement, it is to be observed that when the principals act as arches, notwithstanding the inequality of their thrusts, the strain on the wall-plate will not vary correspondingly, owing to the smaller radius of curvature at the end of the longer axis and the different angles which the lines of tension on the wall-plate therefore make with those of the thrusts. In

fact, the calculated thrusts of the principals do not vary materially from those which are necessary to keep the wall-plate in equilibrium. Supposing, however, any unexpected disturbance to arise, the tendency to loss of shape would at once be arrested, for the lower members of the principals would come to the rescue and get into full work as tie-rods before damage to the walls could occur. There is another element of strength in a roof of this construction which should not be lost sight of. Each principal is equal to carrying the weights to which it can apparently be subjected, whether acting as an arch or as a trussed girder, but if any weakness existed in a principal, it would, from the polygonal form of the purlins, receive much support before mischief was done. The purlins towards the crown must suffer compression, and those on the haunches get into tension as the crown of the roof sinks, and any other change of form would be resisted in a similar manner.

Again, the especial defect of girders of this form as respects lateral and sudden strain from wind is here in a great measure obviated, for not only is the pressure upon any particular half-principal transmitted through the purlins to its neighbours, but the movement of the central curb on which such half-principals rest will be resisted by the series of thrusts transmitted to it by the opposite radiating half-principals resting on and distributing their thrusts over a large arc of the wall plate on the side opposite to that in which the impetus is given. The case, in fact, is almost as different from that of similar trussed girders resting on parallel walls, as a wire meat-cover standing firmly on the metal ring at its base differs from a simple arch of the interlaced wire of which it is formed standing on two pieces of unconnected metal as a base.

Before leaving the question of the roof, I should mention that the iron work was all prepared by the Fairbairn Engineering Company, and that we derived much valuable assistance in modifying certain details of our original plans from Sir William Fairbairn, who was always as ready to discuss any question connected with it as if he had been personally responsible for the design.

I have little time for entering upon any constructive details, but I ought not to pass over one or two expedients of a somewhat novel kind which were ventured on. The whole of the main wall was constructed of hard Cowley stocks set in Portland cement with 3 parts of sand. Portland cement was also in all cases used for the concrete necessary to bring the gravel surfaces which were to receive the foundations to a true level, and to fill in the excavation in the clay bottom, which extended on the south and south-east sides over one-third of the area occupied by the building. The outer wall, built in bricks made by the contractor, was also brought up to the level of the shallowest footings in Portland cement mortar of the above composition; but all above this, and all the cross walls and the walls within the main wall were executed in mortar made in a mill, with 1 measure of grey lime previously slaked, 1 measure of Portland cement, and 6 measures of sand. The set of this mixture was sufficiently rapid to prevent any settlement taking place which might bring an undue strain on the terra-cotta dressings. It also enabled the main wall to be completed to its full height, and the roof to be commenced before the outer wall and cross walls were brought up, and in no instance did any such inequality of settlement from this cause take place as to produce fracture. The outer wall was, of course, delayed for the terra cotta. Delay in the supply of this material appears to be an ever irritating difficulty in its use.

The plastering used on the interior walls merits perhaps some attention. Instead of making the lime into coarse stuff, as is usually practised, and finishing with lime or guaged putty, the grey chalk lime of the Medway was ground to a powder and made into mortar on the following system:—One quarter of a cubic foot of plaster of Paris was stirred into a bucket of water and thrown into the pan of an ordinary mortar-mill, so as to make a milky fluid of the plaster of Paris; another bucket of water or so was then added, and 5 cubic feet of the ground grey lime gradually added, with the addition of

more water, the mill continuing in action the whole time until the pan contained a thin slip of the lime and plaster. To this mixture 30 cubic feet of sand were added and thoroughly incorporated with it, and the mortar was then ready for use. Thus treated the lime sets without slaking, and makes what I have termed "selenitic mortar."

For the finishing coat in rough stucco, the quantity of sand was reduced to 20 cubic feet, and after the first coat was put on the wall, the plasterers could in a few hours' time follow on with the finishing coat. For the first coating on lathwork the usual quantity of hair, but unbeaten, was added whilst the mortar was being incorporated, and the ceilings were finished with a mixture of slip prepared as before, with 1 part of chalk and 2 parts of sand for every part of lime used in the slip.

The whole of the outer corridors, staircases and crush-rooms, and all the private and refreshment rooms round the building are as it is termed fire-proof, no wood being used in their construction beyond that of the doors, windows, and the wood slips used to carry the concrete and tiled floors. Probably, in the case of a fire in the interior of the Hall, the title would not be belied, for the inrush of fresh air would be so great as to keep all without the auditorium perfectly cool. Since also the audience empties itself into these corridors and crush-rooms in a few minutes, there is no great likelihood of loss of life in the event of a fire occurring. As precautions against fire, hydrants are fixed at several points on each floor level, the whole being in communication with 30 tanks on the picture gallery roof, containing in all nearly 50,000 gallons of water. These tanks are supplied from a well sunk through the London clay into the chalk, in the rear of the building, and they also receive the rainfall on the large roof. The hydraulic lift is supplied from the same sources.

In the warming and ventilating arrangements I had the assistance of Mr. W. W. Phipson, who has had great and varied experience in the heating of large buildings. Coils of hot water pipes are placed in three separate air-chambers, under the arena, the amphitheatre stalls and the main corridors of the building respectively. The heated air from those in the arena ascends through the insterstices of the floor; that from the coils under the amphitheatres through the risers of the steps on which the seats are placed; and that from beneath the main corridor finds its way through passages in the wall into the boxes, the picture-gallery, the corridors, the refreshment and private rooms and small lecture theatres. The external fresh air is forced in by two fans 5 ft. 9 in. in diameter, each worked by a 5-horse power engine, and blowing right and left through passages provided for the purpose into the three above-mentioned air-chambers. It may also be drawn through them by the ascensional current of heated air in the Hall itself, which, when the gas is lighted, or the building warmed in cold weather, exerts an enormous force. The amphitheatre and corridor air-chambers, with their systems of coils of hot water pipe can be together utilised for the Hall or for the corridors and private and other rooms. In order to preserve equality of temperature in all parts of these chambers, the coils of hot water pipe are divided into sections, each section having its own hot water generator, in which the temperature is kept up by a supply of steam from three 25-horse power steam boilers at the back part of the building. There are sixteen such generators, each supplying its own system of pipes, with hot water and admitting of being put into action or thrown out at will. The total amount of heating surface in the various coils is represented by about 28,000 feet, of 4-inch hot water pipe.

The chief difficulty in connection with the management of the warming and ventilation of such a building is the control of the inward draft when the doors are open from the ingress and egress of the audience, but by carefully attending at these times to the closing of the louvres of the upcast shaft through the centre ring of the roof, this draft can be controlled.

The conditions prescribed for the exterior were, as I have said, that the façade should consist of red brick with terra-cotta dressings. The subject of terra-cotta as a decorative building material has

been so fully treated of by Mr. C. Barry that it is unnecessary for me to do more in relation to its use in the Albert Hall, than refer briefly to the principles which guided us in its application and treatment The terra-cotta material was considered simply as a superior description of brick, to be used in conjunction with plane surfaces of a somewhat similar material, but of another colour. It was though therefore unnecessary that the lines and edges should have the precision of stone-work given them, or that the blocks should be of large size. It was further judged that delicate modelling would be out of character with a building which must be of very massive appearance, and which should depend more for its effect on the sweep of its lines than on exquisite finish. These opinions were held strongly by Mr. Townroe, to whom the Hall is indebted for the actual modelling or immediate superintendence of the whole of the modelling work, and I judged them to be correct. Many, undoubtedly, think that the modelling is too coarse, but I have been gratified to observe that the eye of the painter is generally pleased with the picturesque effect which this mode of treatment has imparted, an effect to which, doubtless, the varied and rich tints of the material itself have largely contributed.

The terra-cotta was all supplied by Messrs. Gibbs and Canning, of Tamworth. The blocks for the preparation of the moulds were supplied to them by us, and the terra-cotta work was fixed by masons furnished by the building contractors.

The terra-cotta of Messrs. Gibbs and Canning is prepared from fire clay without foreign admixture, and is burned at a high temperature, such as promises to render it very durable; the blocks are not made in the manner followed by Messrs. Blashfield and Blanchard, with cells which have to be filled in with concrete or grouting, but are chambered from behind, so that the brick-work of the wall can be built into them. It is necessary, therefore, in estimating the cost of fixing this terra-cotta to allow for the extra brick-work necessary, but of course there is a saving of grouting and concrete. This system appears to me to make a better job than the blocks with the cells closed at the back.

The red bricks employed in conjunction with the terra-cotta were supplied by Mr. W. Cawte, of Fareham. They are very heavy and hard, having, if I may use the expression, a metallic looking, and slightly conchoidal fracture, are little absorbent, and are for beauty of tint unsurpassed by any bricks in the kingdom. I was indebted to Mr. Gilbert Redgrave for the whole of the work connected with the preparation of the terra-cotta, as well as for his general advice and assistance in every part of the work. Mr. Verity was charged with the preparation of the constructive working drawings.

It will be observed that on the exterior of the wall of the picture gallery in the original design, the surface was broken with decorative panels of geometric design. It was suggested to me by Mr. Henry Cole that this wall gave a fine opportunity for a mosaic picture of figures which he thought should be considerably larger than life. My assistant, Mr. Townroe, on the other hand, while he approved of the notion as much as I did, was strongly in favour of reducing the figures to nearly half life size, and Mr. Gamble, who was much consulted throughout, and who was my boldest adviser in most cases of doubt, supported him. In this conflict of views, I resorted to the counsels of the weak and prudent, and adopted the middle course, which had to my mind this recommendation. The first idea of a spectator would be that they were life size, and although the apparent magnitude of the building might be enhanced by a reduction of the figures, it was better that such an expedient for producing effect should not be attempted, as the balcony immediately below it, with or without living persons standing on it, would certainly reveal the truth. On the other hand, I saw no reason to reduce the apparent size of the building for the sake of a fine mosaic picture. The figures, by the advice of some of the artists who undertook to prepare the

designs were finally made something over full life size. It was at the same time arranged that the colours should be buff upon a chocolate ground, and that the outlines should be black. These points were settled in conjunction with Messrs. Pickersgill, R.A., Marks, A.R.A., and Yeames, A.R.A. The other artists who contributed designs were, Messrs. Armitage, A.R.A.; Poynter, R.A.; Horsley, R.A.; and H. Armstead. The frieze was divided into sixteen lengths of about 50 feet each, some artists taking two or three such lengths, and the sum accepted in payment for the work was so moderate as to entitle these gentlemen to the warm thanks of all who are interested in the application of pictorial art to architectural buildings.

This valuable series of designs is exhibited this evening on your walls. They are drawn on a scale of 6 feet 6 inches to the foot, and the task of enlarging them to the size of the proposed mosaic reproductions was entrusted to Sergt. Spackman, of the Royal Engineers, who was fortunate enough, as I believe, to make the enlargements to the entire satisfaction of the artists. He prepared small photographic negatives from the originals, and by means of a camera, illuminated with a lime light threw an image of the required size on to a screen covered with paper, upon which the necessary outlines were then put in with black lines. Sergeant Spackman, who is himself an artist, determined as a rule the thickness of the lines to be used, but on this point he consulted the artists whenever he was able to do so. The thicknesses of the tesseræ employed in translating these enlarged pictures varied from $\frac{7}{8}$ of an inch to $\frac{1}{4}$ of an inch in five gradations.

It would occupy your attention too long to describe the process by which the mosaic workers produced the actual ceramic pictures on the walls of the building, and I have said sufficient to enable an opinion to be formed of the feasibility of the more general adoption of this species of mural decoration. I would only observe that the flat treatment in this case was not selected from a conviction that it is in itself superior to a treatment in relief for exterior decoration, but because the latter mode would have been very difficult or impossible, for two reasons:—First, it would have been hard to find a body of modellers who could have executed in the given time, eight hundred feet of full size figures in relief, with the same degree of excellence as could be secured by adopting the work of the painter instead of availing one's self of the sculptor's art. Secondly, if this difficulty could have been got over, the means at my disposal were quite insufficient to have met the expense of executing the work by the assistance of the latter. The total cost of the frieze, including the designs, their enlargement and fixing was £4426., and its area is 5200 square feet. Has this decoration been too dearly bought? To say that another mode of decoration would be more effective, if that mode be impossible under the conditions of the case, will not settle the question of the mosaic flat treatment being or not being one that ought to be repeated. In discussing the question, the facility with which the artist's work can be effectually rendered in mosaic work without much artistic feeling or knowledge of the human figure on the part of the operator, ought not to be lost sight of. For modelling in relief every workman employed must be an educated artist, unless the architect is satisfied that want of art shall be the characteristic of the work. I venture to suggest, also, in favour of a flat treatment, that in London soot deposits and birds' nests have somewhat marred the effect of the sculptured figures in the pediments of our public buildings.

The Messrs. Lucas Brothers were the chief contractors, and the well known character of their foremen, their boldness in meeting the views of the architect, and their ability in coping with the most formidable difficulties did not forsake them here. For clerks of the works I had Mr. Hemsley, who showed the most zealous attention to his work, and Mr. Sankey, who superintended the preparation and fixing of the roof to my entire satisfaction. I was also much indebted for assistance to many other gentlemen, but I must not detain you by particularizing the nature of the assistance they rendered. I

ought not, however, to pass over the name of Mr. Charles Stephenson, who afforded me great assistance throughout the whole work.

The chief points of interest in connection with the construction of the Albert Hall have now I think been mentioned to yon. To have given a complete description of the building would, as I have already said, been impossible within the time prescribed for the reading of this paper. I trust, however, that the questions which I have touched upon with such imperfection, will raise discussions that will throw ample light upon them. It is unnecessary for me, I feel sure, to crave your forbearance for this imperfection, whatever may be the severity of your criticisms on the work which, in reliance upon the assistance to be derived from numerous models and the opinions of my friends and advisers, I have been bold enough to execute.

THE PRESIDENT.—Before attempting to convey to Major-General Scott our thanks, I am anxious to hear any remarks that may be made by several engineers, who I believe are here. I see Mr. Gilbert Redgrave present, and I hope we shall have the benefit of some further remarks from him, and also from the other gentlemen who have aided so cordially in their several departments in this great work.

Mr. GILBERT R. REDGRAVE, Visitor.—I beg to thank you, Sir, for the honour you have done me, but I had no idea of taking part in the discussion. As, however, you have asked me to say a few words, I will allude to certain points with reference to the terra cotta and mosaic work to which Major-General Scott has necessarily only referred in general terms. He has told you that the original designs for the frieze furnished by the artists mentioned, were enlarged by means of photography and the magic lantern to the size which you see in the corner at the end of the room. Having obtained the enlarged designs, they were then handed over to the mosaic workers, principally students in the female school of art. The outline of the figures were first drawn on paper, in black. The tesseræ used were small square encaustic tiles of the tint shown in the drawings, which were stuck on to the outlines by means of gum, and in any bends or curves in the lines, and in parts where the thickness was more than the thickness of the tesseræ, it was necessary to chip them to make them fit. Having the whole outline on paper, fitted with the black tesseræ, the filling up of the ground with the chocolate and buff coloured tiles was done by unskilled mosaic workers, and in this way the whole design was put together on the paper ground. It was then necessary to make the mosaic picture into a solid slab, and for this purpose it was placed face downwards on a table rendered with cement, built up in the form of the outside curve of the hall. The back of the mosaic picture was then grouted with Portland cement, and common plain tiles were bedded into the cement in two thicknesses. The mosaic was thus built up in pieces, each 2 feet wide and half the height of the frieze, so that the entire circumference was represented by 800 slabs, 2 ft. wide, and 3 ft. 3 in. high. As soon as the cement had set, the paper was washed off from the face of the finished work, and then for the first time the front of the mosaic picture was seen. The cost of the entire mosaic work was, for the design, 3s. 1d., enlargement, 11d., execution and fixing, 13s. 4d., making a total cost of 17s. 4d. per square foot.

Another point of interest in the building is in regard to the terra cotta work. The designs furnished by us were handed over to plasterers working under our direction, and they made blocks in plaster of Paris to the requisite shrinkage scale for terra cotta, viz :—13$\frac{3}{8}$ inches to the foot. We at first sent to the manufacturers only the detailed drawings made to that scale, but we subsequently found it necessary to furnish them with a model of each kind of block made to the right shrinkage scale in plaster of Paris. In a large building like this, it was necessary to have a classification of the blocks and this was done by means of a letter of the alphabet, so that each course round the building

should form a distinct letter. We also had particular signs for external and internal mitres. That for the external mitre was a cross, and for the internal mitre the letter with a circle round it. The difficulty in working terra cotta consists in the inequality of the shrinkage; and in making great lengths of moulding it is one advantage to have at the end of each block a small depression of the surface to form a chipping piece. This is effected by recessing the sides of the block so as to give a projection of about half an inch all round the outer edge, which the workman can chip away if necessary, to reduce the length of the block. You rarely find a difficulty from getting the blocks too short. The fact is that the manufacturer provides for the extreme shrinkage, and blocks less fired than others shrink less, and thus the length of the moulding generally becomes over rather than under what is wanted.

Mr. T. ROGER SMITH, Fellow.—(responding to the President's invitation) said: I have listened with great pleasure to Major-General Scott's account of this great work. I fear that I am not prepared to add anything of importance to what has been said by him, I should like however to say how much I have been struck, during the many opportunities which I have enjoyed of seeing this work during its progress, by the many novelties made use of, and I am sure we must all congratulate Major-General Scott upon the success which has attended an undertaking on so large a scale, when so many new materials and new modes of decoration have been employed on a structure of a character never before attempted in this country.

It would be a very satisfactory result if the consideration of this Hall should draw attention to the suitability of buildings for hearing, and to the considerations which govern the adaptation of buildings for hearing and speaking in. The Albert Hall must be looked upon more as a building for music than for speaking, though I can testify that from one end of the building, along the central axis at any rate, a voice moderately raised can be distinctly heard at the other. What Major-General Scott has said with regard to echoes is very true, viz.:—that a great many are found by listening for them. No doubt in that Hall, when nearly empty, echoes can be heard at various points, and with varying intensities, most of which disappear when the Hall is filled, and begin to disappear as it begins to fill. I suppose the hearing was never more perfect in that Hall than when it was to a great extent filled with a forest of scaffolding, which "damped" or deadened the sonority of the body of air in that vast space. When this was removed and the glass ceiling without the velarium was exposed, there was an excessive amount of resonance. But I believe it will be found that every building which is thoroughly successful as a music room, is too resonant when perfectly empty, therefore the point to be aimed at is to hit the happy medium between a building where the excessive resonance when empty will not be sufficently "damped" by a moderately full audience, so as to result in clear distinct sound, and one in which there is no resonance at all. On the whole I think that happy medium has been secured in the case of this Hall. You must judge of a large room as it behaves when filled; and when filled by an audience you hear in the Albert Hall well, and with extraordinary distinctness. This is no doubt very much due to the form of the building, and to the fact that the auditors are placed in favourable conditions for hearing, that a direct ray of sound reaches every auditor in every part of the building, that reflecting surfaces of an injurious character are to a great extent masked, or so kept back as not to influence the sound; no doubt also a great deal of influence is exerted by the wooden lining which Major-General Scott has described as extending so largely over the walls. In other buildings such a lining has been found to contribute largely to acoustic success, notably in the Surrey Music Hall, built by Mr. Horace Jones. A large amount of wooden lining was employed in that building, and musical sounds were there wonderfully well heard.

Great interest has been naturally felt in this work, and I am sure we must all feel deeply indebted to Major-General Scott for giving us so lucid and well illustrated an account of so important a structure.

MR. J. GROVER, Visitor (also responding to the President's invitation), said:—General Scott having mentioned my name, I will endeavour to point out a few of the practical details with respect to the roof. You will see on the drawing that the ribs are stopped upon a double centre ring curb, and are not carried through. The reason for that is obvious; if they had been clustered into one point it would have been difficult to carry out the connection, therefore it was determined to finish all at a certain distance from the centre. With regard to the forces that come upon this centre ring, as in the case of an arch, the thrust at the springing is equal to the pressure at the crown; the compressive strain upon this inner double member is equal to the extensive strain upon the lower outer curb or wall plate. In calculating the strains that come upon the roof it was necessary to consider, in the first instance, how they should be arranged. General Scott determined that the roof's structural part should be so executed that it should be capable of standing without the assistance of the outer curb at all; that is, it should carry itself by its own inherent strength. The details show cast-iron shoes, and the ribs of wrought-iron fit into them on a curved bed. At the back of the shoe wrought-iron keys are driven in in such a way that they can be released by the stroke of a sledge hammer. The consequence of this arrangement is that you may go round this roof, and by looking at the adjustment of these wedges at once ascertain whether every member of the rib is doing its fair amount of work, and whether every part is in proper tension and compression. Owing to the subsidence of the work during construction these keys became very tight; but that was the theory on which the construction was based, viz., that the framework should be capable of standing by itself till the covering came on. When the covering came on this great ring or wall-plate came to the rescue, and the strains produced by the whole weight of the covering are mainly carried into this.

If you look at each rib as a girder, as in the case of roofs like that of Charing Cross station, you have the lower number in tension and the upper number in compression; therefore it was desirable that the heavy strains of tension in the former member, when the covering came on, should be met by the strains of compression, which would cancel them. That was carried out in theory, and was practically successful. Necessarily the roof was constructed of very light iron. These ribs are of only $\frac{5}{16}$ths of an inch thick plates in some parts, so that not much metal is thrown away. There was much greater thrust on the curb at the top, and that was made of stronger section in some parts than in others, and if you examine it you will find there is half as much again metal in the top number as in the bottom The roof during construction was mainly carried by the great central scaffold, and on that there were wedges, and those wedges were kept in to form the centre on which it was built; and when struck there was not above* half an inch subsidence; and when you think what a large structure it is, that was an exceedingly small amount of subsidence.

Gauges were put on, and it was found that there was a slight rise and fall with variation of temperature. The roof was covered with glass down to a certain level; the water was collected in gutters from ridges and brought down in pipes, running over the tops of the ribs. Looking at that roof, and considering it, you will naturally say, "Why should not these purlins be made each to help in doing the work of this great wall-plate curb?" Manifestly they would do so with a rigid rib, and the section of the curb might have been reduced by the amount which there is in these purlins, but that was not desirable or advisable. It would have involved difficulty in the connections, and it would not

* I see, on looking at the report of the event, that this deflection was really only $\frac{5}{16}$ths of an inch.—J. W. G. See *Builder*, May 21, 1870.

have been safe to trust ultimately to anything short of the base plate on which the structure stands. There was scarcely any cast iron used except in the shoes; all the rest is wrought iron. The necessary vertical struts or distance-pieces are angle-iron, with little cast iron struts and bolts passing through them, and the diagonal tie-rods come in to equalize unequal strains. The ribs are generally of uniform section. An extra plate was used in part on the bottom flange of the major axis ribs. If you can conceive that to be equally loaded at all points, it would hardly have been necessary to have this, but as there is inequality of pressure to be met the strains increased at that point. Each rib was calculated separately, and the forces which came upon it carefully investigated. The weight was taken out in place of each portion of the covering, and of the roof itself; the centres of gravity were found, and equations formed, which gave the strains passing through at every point.

I may, in drawing your attention to the general character of this roof, remind you of the prototype of them all, as shown in the roof of the New Street station at Birmingham, built by Messrs. Fox & Henderson. The span of that roof is, I think, 212 feet. That roof was a very successful and cheap one: but it is different from this, inasmuch as the lower member was entirely in tension, and was consequently formed of rods about 4½ in. diameter. In this case we have a difference, because certain compressive strains come in. The struts are similar to those here. The great strength of the centre curb as compared with the rib itself will strike any one; but when it is remembered it has to carry the collective thrust of all these ribs, there will not be much occasion for surprise, particularly as each force has to be resolved into the angle, which is exceedingly small. Supposing the structure to be on the point of rupture, a very considerable alteration might take place in the form of any one rib—so serious as to endanger the whole thing before the purlins would be stretched beyond the limits of elasticity.

Mr. W. W. Phipson, C.E.—General Scott has already so fully described the system of heating and ventilation adopted that I will only confine myself to a few practical remarks. The fans supply conjointly 4,000,000 cubic feet of fresh air per hour, which is an ample allowance for a full audience. From experiments I have made during the concerts, I find that after an hour from the time the people are admitted, the temperature throughout the whole height of the building is nearly equal, though before the admission of the public the galleries are always about 4 degrees lower than the arena and amphitheatre stalls. The whole rise in the temperature from the time the public is admitted to the end of the performance is about 7 to 8 degrees Fahrenheit. There is one point I wish to draw attention to —that is the employment of steam heaters instead of hot-water boilers for heating the coils, which had they been adopted would have involved the carrying down of main walls to obtain the required depth for circulation. There was nothing original in this arrangement, which has been carried out by me abroad and in this country several years ago, but this is, I believe, the most extensive application of this principle of heating surface. The steam is conveyed from the boilers to these heaters, which are in communication separately with the coils. In this way two or more heaters may be at work, or the whole of them, according to the requirements. The heating surface in each is about 25 square feet for 1,000 lineal feet of 4 in. pipe.

In reply to a question from Mr. Morris, Mr. Phipson added—There are two systems of heaters used: one circular in form, and the other square. I believe the square form does its work the most economically; but in no case does the steam blow directly into the water.

Mr. A. Waterhouse, Fellow.—I would call attention to the fact that in the Albert Hall every body can sit, and see, and hear with perfect ease and comfort. This is the case to a degree not to be found in any other building with which I am acquainted.

With regard to the terra cotta, whatever its defects, it has one great merit as used in this building, in that it is put in its place without any attempt to chisel it down to a true surface, consequently, so

far as I have observed the material retains its vitrified face, and shows no sign of discolouration at the edges. If successful use is to be made of terra cotta, this treatment must be insisted on.

Mr. BENJ. FERREY, Fellow.—I have the pleasure to propose a vote of thanks for the admirable address read this evening in relation to this great work. It is a building of such importance, that it is difficult to follow or enter upon all the interesting matters connected with it. We have also been favoured with some valuable observations of a practical nature, by gentlemen who have taken part in the work. I think the building itself is a great credit to the country and to all connected with it. I beg to propose without further remarks that the best thanks of the meeting be voted to Major-General Scott for his admirable description of this work.

Mr. C. F. HAYWARD, Fellow.—I hope I may be permitted to second that proposition, I have listened with pleasure to what Major-General Scott has told us, but there are many here who, like myself, are personally indebted to him for having taken us over the building last summer during the Conference, and shown us the things described more in detail. I would venture to say a word on the subject of the terra cotta used. I cannot think it is always the best way of treating terra cotta, to take it direct out of the mould in which it is made, without attempting occasionally in the more delicate parts to give it a better finish, inasmuch as it is capable of finish, *before being burnt*, at the hands of the same workman, who having sufficient artistic skill would be capable, if it were stone, of carving it. There are many persons employed for such purposes in terra cotta manufactories (especially at Mr. Blashfield's works) capable of perfecting the moulded work with hand labour as much as is desirable, in fact more than is desirable if you allow them. When that is done, and when the block is fired, you have as much the handy work of the individual as if the thing were carved out of the solid stone, and it can be secured from being produced again by breaking up the mould, and thus a thousand varieties could be executed from a few moulds without the fear of their being copied *ad infinitum* in other buildings.

I admit nevertheless that there are times and ways in which terra cotta can well be used without that perfection of work, and no doubt it is desirable occasionally to do so, but I refer to this subject lest it should be thought there was only one proper way of treating terra cotta, viz.: the manner adopted in the Albert Hall, of not touching the work after it is moulded.

I think any one who wants to study iron construction could not have had a better opportunity than by inspecting this roof during its progress, and it is especially satisfactory to me this evening to have heard such a description of it from the gentleman before me (Mr. Grover) who has had so much to do with its construction, and experience in this kind of work. We are also indebted to the other gentlemen who have supplemented the paper with their remarks.

MR. W. F. YEAMES, A.R.A. (Visitor).—I have little to say about my share in this great undertaking, having furnished General Scott with only a portion of the designs for the frieze, and those of my painter friends who assisted, were much pleased, however, in working out these designs. Before commencing them we met at the South Kensington Museum, where General Scott had designs enlarged to the scale you see in this room, the scale they were finally to be executed in, and these were put up at the proper height of 84 ft. These experimental designs had backgrounds of lighter and darker hues, with black outlines of different thicknesses. We decided on the darker background and the broad outline, thinking they were the most visible at a distance. The frieze being placed at so great a height had to be simple in treatment, the figures to be left a good deal apart, and foreshortening and grouping to be avoided; and what we studied most was to give an ornamental aspect to the frieze. From time to time, whilst the mosaic work was in progress, we visited the Museum to inspect the reproduction of our designs, and were struck both by the exactitude of their enlargement and the faithful rendering of

the character in the heads, in spite of the roughness of the materials; and I have only to add that we were much pleased in having an opportunity to assist in this remarkable architectural construction; and indeed painters are always gratified when the sister arts combine in works of this kind.

The PRESIDENT.—At this late hour I shall only say with what pleasure I act as the mouthpiece of the Institute in offering our best thanks to Major-Gen. Scott for his kindness in coming among us to-night, and giving us so interesting and graphic a description of a work which leads to so much thought. When one bears in mind the magnitude of the work, never before attempted, and its special form, which involves great difficulties with regard to the roof (for we know how apt an ellipse is to get into the form of a circle) we have much to admire—not only its construction, but its qualities in regard to sound, ventilation and warming—to all of which an immense amount of thought and care must have been given. Of the great success of the work, all who have been within this building must be fully convinced. The matter has been so clearly explained, that I need only ask General Scott again to accept our very best thanks.

MAJOR-GENERAL SCOTT.—I am much obliged to you, gentlemen, as well as to the President, who has referred to the work which I have attempted to describe in such a favourable manner. It is a continuation of that kindness which I have always received from architects since I have been employed in London. There are one or two points of the discussion on which, if you will allow me, I will say a word. And first, on the question of the acoustics of large rooms. Mr. Roger Smith has alluded to the extraordinary purity of the sound in the building I have described. It is a bold thing for one, not a musician, to hold on musical matters an opinion opposed to musicians generally; but I firmly believe that the Albert Hall will be found, on account of its great size, more perfect than most other buildings for chamber music. The general opinion has been that chamber music is not suitable for such a hall as this. I believe this to be an error. It appears to me that if delicate music be performed in a small room there must be reflections from the walls which will intensify some notes as compared with others. Music is never heard with greater purity than in the open air, and especially on a surface of smooth water, where there is nothing to interfere with the sound; and I cannot help thinking that in buildings the farther the walls are from the sources of sound the purer the sound of delicate notes must be. It is difficult, however, to obtain reliable opinions as to the effect of music in buildings. On one occasion when we had four violins playing in the centre, two or three musicians present told me they never heard chamber music more perfectly, or in greater purity; while another gentleman, an eminent musician, said he was certain all the instruments were being over-played in order to make them sufficiently audible, and in this opinion he persisted, though the musicians themselves declared it was not so.

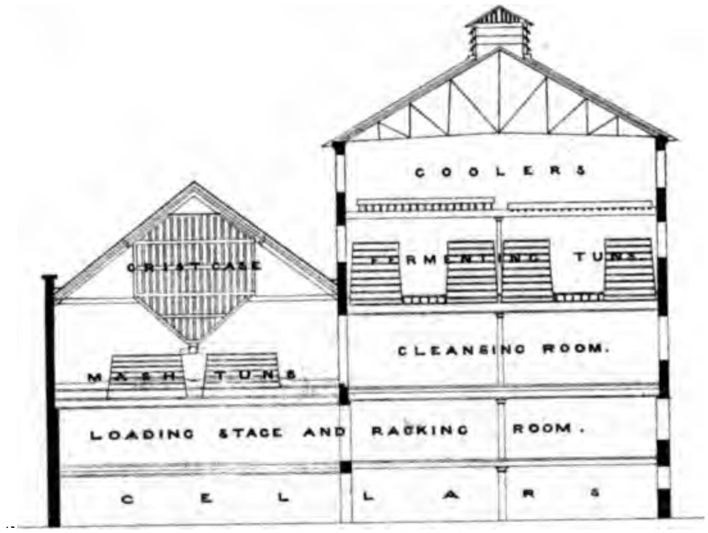
I had many friendly contests with the gentlemen who assisted me with the roof as to the shape, which, considered in an engineering point of view only, it ought to take. My first idea was that it should have that form which is undoubtedly best from this point of view: that is, that the ribs should be alike, and that they should spring from the wall-plate in a perpendicular instead of a skew direction, as now, thus making the attachment of the purlins difficult. By the adoption of this engineering view of the question, the purlins might probably have been made to do the work of the wall-plate to a large extent. The plan adopted is however, on the whole, a benefit to the architectural appearance of the interior, for that which was best from the engineering point of view would have given an ugly shuttle-shaped figure in the centre of the ceiling instead of the present ellipse.

Let me add one word as to the terra-cotta modelling. I do not think Mr. Gilbert Redgrave, if I know his sentiments correctly, would contend that one ought not to attempt to do anything to the clay after it comes from the mould, and before it is burnt, though he objects to its being touched by the terra-cotta workman. Mr. Redgrave knows that when we have had any very delicate piece of modelling

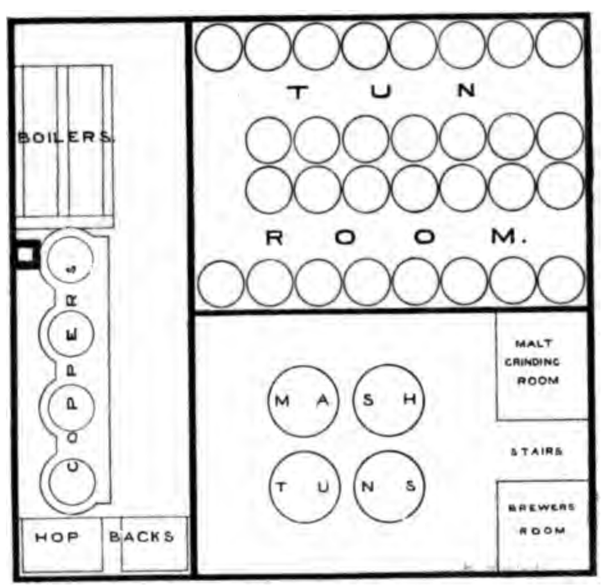
work to do, we have always sent an artist down to the works to touch it up before it went into the oven, and I am sure he approves of this. With reference to the point in connection with the use of terra-cotta, to which Mr. Waterhouse alluded—I mean rubbing off inequalities—I think he is quite right. As surely as you scrape off the surface from terra-cotta it undergoes degradation, and readily takes up soot and dirt. We tried it in one part of the Hall, in one or two of the door-ways, and even there, though protected somewhat from the weather, we were obliged to give it up. I again thank you for the kindness with which you have received my paper, and for the patience with which which you have listened to these remarks.

The discussion having then been brought to a close, the meeting adjourned,

PLAN & SECTION
of a
200 QUARTER BREWERY.



SECTION THRO' A 200 Q^rs^ BREWERY

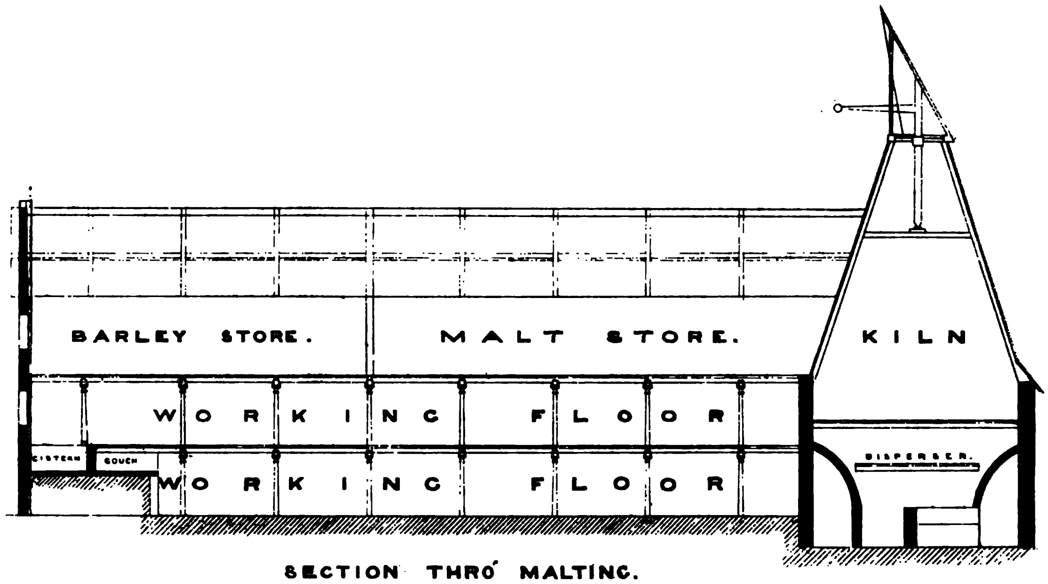


PLAN OF A 200 Q^rs^ BREWERY.

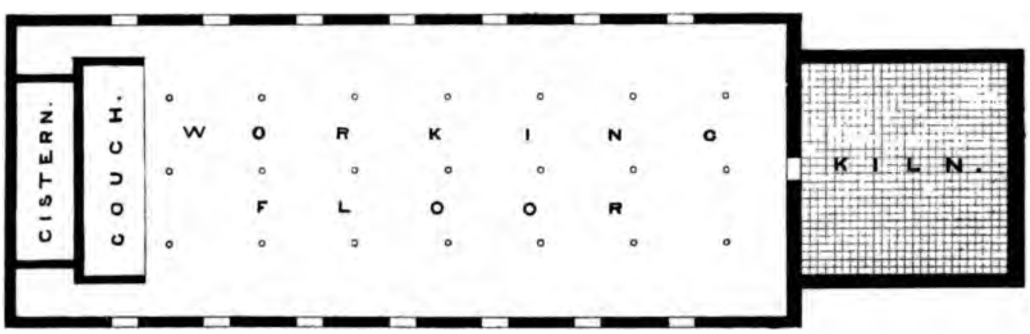
Scale of Feet.

GEO. SCAMELL

PLAN & SECTION
of a
40 QUARTER MALTING.



SECTION THRO' MALTING.



PLAN OF MALTING

Scale of Feet

GEO. SCAMELL

Photo Lith. for the R.I.B.A.

Royal Institute of British Architects.

At the Ordinary General Meeting held on Monday, 5th of February, 1872, the following Paper was read, HORACE JONES, Vice-President, in the Chair :—

ON THE CONSTRUCTION AND ARRANGEMENT OF BREWERIES AND MALTINGS,

By GEORGE SCAMELL, junr., Associate.

IT may at first appear to some present that a paper upon the arrangement and construction of a Brewery or Malting is scarcely a suitable subject to dwell upon *here*, and to devote an evening to; but when we consider the work continually going on in the various breweries throughout the United Kingdom, I believe that the few remarks I have to make will be found of general interest to the profession. It may tend further to impress upon us the importance of the subject when we find by referring to the estimates lately prepared by Professor Leoni Levi for Mr. Bass, that the capital invested in breweries and maltings, &c., in the United Kingdom, amounts to £12,400,000, and that the total number of persons employed in the trade is 246,000, or, including the retail trade 846,000. The number of breweries being worked now is over 4500, and the quantity of malt annually consumed now amounts to 6,250,000 quarters; the total annual income to the revenue of the country from licenses for brewing, malting and the duty upon malt, being upwards of £6,850,000.

Before commencing the description of what a Brewery should be, I must trespass upon your time a few minutes, and give a slight sketch of the method of brewing, in order that any one present who is not acquainted with the process may be the better able to follow me in the remarks I am about to make. Up to a certain point the method of brewing is similar whether brewing porter, stout, ale, or upon the Burton, Scotch, Yorkshire, or other systems, the process being as follows :—

The method of brewing, as practised by our great brewers, consists mainly in the extraction of a saccharine solution from the malt, and boiling with it certain proportions of hops, by which the aromatic bitter is extracted from them, and in converting this solution into a fermental and sound beverage. To accomplish this, the malt is first crushed between cylindrical iron rollers, so adjusted as to break every corn. When so bruised, it is intimately mixed with hot water, by means of a mashing machine, which may either be fixed outside or inside the mash tun, which tun is a circular vessel with a perforated double bottom; from this vessel the wort flows into the underback and then into the copper, where the hops being thrown in, boiling commences. This is continued until the wort is of the required specific gravity, when the contents are let off into the hop back, from whence it flows, or is pumped into the cooler. This hop back also has a perforated false bottom, through which the wort runs, leaving the spent hops to be disposed of. The coolers are large shallow vessels exposed as much as possible to the air, but as during the greater portion of the year, they would not produce the desired effect with sufficient rapidity, almost all brewers have cooling machines called refrigerators. By these means the wort is reduced to the required temperature, after which it is allowed to flow into the fermenting tuns, where the yeast is added, and the fermentation ensues; up to this point

all systems of brewing are the same, the difference being in the manner of separating the yeast from the beer, when, as it is technically termed, the beer is *cleansed.* By the Burton system the process is to run the beer, yeast, &c., into small casks, called *union casks*, fitted with a short length of copper pipe, through which the yeast works out; or, again, in some cases, the yeast is skimmed off the top of the fermenting tuns, the beer afterwards being allowed to settle in settling squares, or, as in many establishments, the beer is "cleansed" in small casks resting on wooden troughs or "stillions." Seeing there are so many varieties in the manner of brewing, it is absolutely necessary to have the views of the proprietor very clearly expressed before commencing the design of a Brewery. Having been instructed fully, the next thing is to consider how best to carry out the instructions.

The capacity of a brewery is always spoken of by the number of quarters of malt that can be mashed at one time, *i. e.*, if the mash tun will contain ten quarters, we speak of the brewery as a ten quarter. The contents of the tanks and all vessels are guaged in barrels; a barrel being 36 gallons, or 5·77 cubic feet.

General Arrangement.—As far as possible the various utensils should be so placed that the wort may flow from one vessel to another, through the whole process, without pumping, *i. e.*, the mash tun should command the copper, the copper the hop back, the hop back the coolers, and these again should command the fermenting tuns, cleansing vessels, &c. Where, however, on account of the great height required by the vessels in a large brewery the buildings would require to be of a great height, it is best to arrange for one pumping, that is from the hop back to the coolers. Occasionally the copper is placed at the top of the building, then the raw wort has to be pumped up from the under back. The majority of brewers, however, object to pumping raw wort, as it is urged that the wort is injured by being subjected to the action of the pump in this state.

A perfectly level site is not as a rule to be selected, as by taking advantage of any natural fall of the ground, even in a large brewery, the vessels may be placed so as to command each other without carrying the buildings to any undue height.

After the selection of the site, the next point to be considered is the position of the well. The proper selection of this place is most important, as the well should be so placed and constructed that there may be no possibility of any sewage or deleterious matter leaking in, as in such a case most serious injury would result to the beer brewed from contaminated water. It should also be convenient for driving the pumps from the engine. The site, generally, should also be thoroughly well drained, all the drains being of rather larger capacity than would suffice for ordinary buildings, and laid to a sharp fall, as a good deal of stale yeast and brewing refuse will find its way into them when the various utensils are washed out and if there is not a good fall, the yeast, from its peculiar nature, is liable to adhere to the pipes, and cause a great amount of inconvenience; this is a point that should be well attended to.

These preliminaries being settled, we will now pass on to the consideration of the brewery. For a large establishment, as a general rule it is best to divide it into three grand divisions, the first containing the mash tun, and the accompanying utensils; hop and malt stores, &c. The second division, which we will call the copper house, containing the wort coppers, boilers, hop-back, and under-back. The third division, the fermenting tuns, which we will call the tun room. All these divisions should be so situated that either division can be enlarged without altering the general arrangement.

In the first division, the following vessels will have to be situated. The cold-water tanks, and which the majority of brewers prefer to have under cover. These tanks are generally of iron, and it is a great

advantage to have them lined with white glazed tiles; if this is decided upon, the tank-plates should be cast with chequers on to form a key for the cement, if the tanks are under cover, and not exposed to the extreme variations of temperature, the expansion or contraction is not found to loosen the tiles. The underside of all iron tanks should be boarded, as if not the moisture in the atmosphere condenses, and the continual dripping is a constant source of annoyance, beside causing damage if any malt or hops may happen to be stored beneath.

A vessel will have to be provided for heating the water for mashing. It should contain sufficient water for the whole brewing, and is generally best made of wrought iron, the water being heated by a steam coil. Occasionally a separate copper with furnace is erected for this purpose. In some instances where expense is not a great object, these vessels are made of copper.

The malt rolls, for crushing the malt, vary in size from 6 in. to 18 in. diameter, and from a few inches to 3 feet in length, according to the quantity of malt to be crushed per hour. Space will be required over them for a hopper for containing the malt to be crushed, and a screen for screening the same. They should be situated so as to be convenient for driving from the steam-engine; but the opinion of the brewer must be taken as to their position with regard to the grist case, as some prefer to have the rolls fixed directly over the case, and grind into it, whilst others prefer to have the rolls some little distance, and allow the ground malt or "grist" to be conveyed into the case by means of an elevation or Archimedian screw, thus giving the grist an opportunity to cool, as the temperature is considerably raised by being ground. The same description of elevators or screws may be used with advantage for moving whole grain. We next come to the grist cases, or receptacle for the ground malt. They are made of wood or wrought iron, in which case they should be flush rivetted on the inside, as the least obstruction will hinder the flow of grist. But on the whole I prefer a case made of thoroughly well-seasoned deal, as grist runs so much more freely on that, than on any other substance. The stuff from which the case is made should be particularly well seasoned, and should be ploughed and tongued, as it is a difficult matter to keep the joints tight, the malt dust blowing through the slightest crack almost as readily as water would. The angle of the bottom should not be less than 45°. The capacity should be sufficient to admit of it containing the whole quantity of malt to be mashed, allowing 12 cubic feet per quarter, with a sufficient margin so as not to necessitate any levelling or trimming by hand. The weight of a quarter may be reckoned at about 3 cwt. Occasionally they are made to hold double the quantity of the mash tun, and are fitted with a division so as to enable two days' supply to be ground. The outlet will have to be arranged according to the description of mashing machine which may be decided upon. If it be an external one, then there must only be one opening. If, however, the grist is to fall into the tun direct, then two or four are best, so as to admit of the grist being pretty equally distributed in the tun. In this instance the outlets should be fitted with slides so arranged that they are all opened at the same time by one wheel or handle. The mash tuns are generally constructed of wood, though occasionally of iron—if so the girders should be as rigid as possible, and if an internal machine is to be used, the framing for supporting the tun must be so arranged as not to interfere with the gearing for driving such machine.

In this division it is generally convenient to place the malt and hop stores; the capacity of these must vary according to circumstances, some proprietors only keeping a small stock. Where, however, it is decided to have large stores, it is found that malt keeps best when stored in deep bins, which bins should be constructed of timber, and if any external wall forms part of any bin, it should be lined with match-boarding, as if malt gets the least damp or "slack," it is rendered unfit for brewing purposes. The lining should be kept as close as possible to the walls, so as not to form a harbour for vermin. It is a convenience to have the bins of unequal size, as it allows of keeping separate lots of malt distinct.

Ten cubic feet of space should be allowed for each quarter. If a porter brewery, a separate store will be required for black or roasted malt. If, again, the brewery is in connection with a malting, and raw grain or barley is to be stored there, according to the Excise regulations such store must have a distinct entrance from the street, and no connection whatever with the brewery. The loft should be so situated that the malt can be easily brought in, and convenient for conveying it to the malt rolls. The hop loft should also be convenient for receiving the hops, and as close to the copper as possible. This loft should have little or no ventilation, and not much light, as if the hops are much exposed they are liable soon to lose their aroma and valuable properties. Provision will be required in this loft for weighing the hops previously to passing them to the coppers. If either the malt or hop loft should be situated in the top floor, the lofts should be ceiled.

The ground floor should be raised at least three feet above ground level, as it then forms a very convenient floor for loading out the beer from, and admits of forming a good cellar, without going a great depth, a particular advantage in swampy soils, as the cellars should be dry. The steam engine may generally be placed on the ground floor, and should be convenient for the boilers. A small office will also be required here. A very convenient office will also be required for the brewer, which is generally best on the mash tun stage or some central position, and should be well fitted up with every convenience for cooling and testing samples, and abundance of room for hop samples. This office should have a good strong light.

We will next consider the second grand division, viz: the copper house. The utensils that should be grouped together in this division are those from which a large amount of steam is given off, comprising the underback, coppers, hop back and steam boilers; by keeping these vessels in a distinct house, the brewery may be kept comparatively free of steam. The underback is a small vessel, and does not often require to hold more than from 7 to 10 barrels, and is used for running the wort into before it enters the coppers. It should be placed as near as possible to the mash tun, and should be ready of access and in a good light, as the brewer in charge will require to get to it continually to watch the taps, whilst the wort is running from the mash tun, it should be so situated as to allow of the wort flowing into the boiling copper. Where sugar is used for brewing from, it is convenient to have a separate vessel fitted with a steam pipe, for dissolving the sugar in before it enters the copper, this vessel should be placed as close as possible to the coppers, and can be made of wood or wrought iron. The boiling in some establishments is effected by fire, in others by steam, this point must be decided by the brewer, who also must decide as to the greatest quantity required to be boiled at one time, as it is very rarely the case that the whole of the brewing is boiled at once; the usual allowance as to the capacity of a copper is that the copper should hold one third more than the quantity to be boiled, to allow for the ebullition. The coppers should under any circumstances be kept as far as possible from the tun room wall, as otherwise the heat given off when boiling will seriously affect the temperature of the tun room; they should be high enough to command the hop back, allowing a good fall for the main for connecting to the same; there should also be a ready way of conveying the hops from the hop loft. The setting of the wort coppers should also be closely attended to; if in London, some description of smoke consuming furnace must be adopted, and in that case the patentee or maker of the selected furnace will give the size of that particular furnace suitable for the size of copper; if an ordinary furnace is to be erected, then for a copper the bottom of which is 7 ft. diameter, a furnace the bars of which are 4 ft. long by 3 ft. 3 in. is sufficient, or for a copper 5 ft. 6 in. diameter, then if the bars are 3 ft. long by 2 ft. 6 in. wide, and so in proportion for other sized coppers. The flues must finish, or as it is termed be *safed* in, so that the top of the flue is just below the level of the least quantity of wort required to be boiled at one time; all flues must be lined with fire brick, set

in fire clay. Such linings should not be incorporated with the settings, but should have an air space of two or three inches left between and be merely connected with the body of the work by a few headers here and there. The great heat is not then liable to crack the setting. It is not advisable to use much iron bond, as such expanding from the heat is liable to split the work. If the copper is set independent of all others, the best arrangement is to split the draught that is leading the flue right and left round the copper, and to unite it again at the base of the chimney shaft, which would be erected over the front of the setting of the copper. If, however, the flue is to unite with some other flue, then what is called the wheel draught must be used, that is, the flue is not divided as in the previous case, but makes the circuit of the copper and unites with the main flue at the back of the copper. Dampers must be inserted in convenient positions for regulating the draught, and soot doors for cleaning out the flues. The space over the copper should be quite clear, as if any vessel is placed above the copper the vapour given off when boiling is sure to condense, and the constant dripping is a source of great annoyance. The hop back should be large enough to contain the whole boiling; in arranging a brewery, as a general rule this may be considered the starting point as regards the levels, as the hop back should not be sunk in the ground, but should have a good space underneath it, as if not, it so soon rusts or rots out; this vessel should be so placed that the spent hops can easily be removed. It is not desirable to have cellars under this building, as no matter how great the thickness of the vaulting may be, the heat from the coppers would keep the temperature of such cellars too high to admit of using them for storing beer in. The steam boiler can generally be well placed in this building, and all the flues connected to the same chimney shaft as the coppers.

With regard to the setting of the boilers: perhaps it may be thought that I am rather trespassing upon the engineer's department, and out of place here in making any remarks upon the subject, but as the architect is invariably called upon when carrying out works of this description to include such setting in the specification, I venture to add a few words on the subject. If the boiler is to be insured in any of the Boiler Insurance Associations, then the plan of the setting should be submitted before the work is carried out, and much trouble may be saved by so doing. The Cornish or Lancashire boiler is now almost universally adopted, that is, one in which the fire tube (or tubes) runs through the boiler. The old way of setting such a boiler was to rest it on a mid-feather wall running the whole length of the boiler: this plan is to be condemned as strongly as possible, as in case of any leakage at any of the seams, the water finds its way to this wall, where it is arrested, keeps the work damp and soon corrodes the shell of the boiler. A plan now often adopted is to set the boiler on a series of blocks, set at right angles to the length of the boiler, as the blocks overlap each other they form a zig-zag passage in that part of the flue beneath the boiler. If the ordinary setting is made use of, the best plan is to have block of fire lumps for the boiler to rest on, where the rivets would come in contact with the blocks, the lumps should be cut out and filled in after the boiler is in its place with fire clay, which can easily be drawn when the boiler has to be examined. The description of damper for regulating the draught should be ascertained before the drawings of the setting of the boiler are prepared, as there are one or two self-acting dampers which require a considerable deal more room than the ordinary ones.

The crown of all boilers should be covered with some non-conductor to prevent the heat radiating, but most certainly not with brickwork, as under such circumstances, if any leakage takes place round the manhole or safety valves it may not be detected until the boiler is seriously injured. Provision must be made for getting into the flues for cleaning out, or for examining the boiler, a drain must also be provided in front of boiler for conveying away the waste water when blowing off. For all practical purposes the chimney shaft need never exceed 75 ft. in height from the furnace bars,

and in designing a shaft the possibility of an additional copper or boiler being erected should always be borne in mind, therefore the area of the shaft should be rather larger than absolutely necessary for the present requirement. Mr. Rawlinson recommends for a tall chimney shaft, that the shaft be carried up square with an internal circular lining of fire brick, thus leaving spaces at the corners for air spaces; such spaces will tend to keep the external work cool and it will not be so liable to split; this is no doubt an excellent arrangement for massive chimnies, but for shafts of ordinary dimensions it is scarcely necessary to go to this additional expense, all that is necessary is to line the bottom of the shaft and about 12 or 15 ft. of the top with fire brick. The area of the outlet at top of shaft may be found by multiplying the number of lbs. of coal consumed per hour by 12, and dividing the product by the square root of the height of chimney in feet, the result being the area of the top of the chimney in square inches. For a circular shaft the diameter at base should not be less then one tenth of the height; the thickness of the work should not be less than one brick for the first 25 ft., and increasing by one half a brick for every additional 25 ft. At the base of the chimney should be an iron door to allow for removing the soot, and it is a great advantage to cause the flues to enter the shaft a few feet from the bottom, so as to form a receptacle for the soot without interfering with the flues.

There should be abundance of ventilation in the copper house, both in the side walls, and also in the roof. The openings in the walls should be so arranged that a copper or boiler can be easily removed and replaced, it always being a great advantage, indeed almost absolutely necessary, that such utensils should be taken in whole.

We will next consider the third division, viz., the fermenting tun rooms: this portion of the brewery should be lighted from the north or east, as it is very important to keep it as cool as possible, where however this is impossible, all openings should be fitted with outside blinds. It is generally advisable to carry up the walls hollow, as by that means, a more even temperature may be maintained in the rooms; the top floor of this building may comprise the coolers, which are large shallow vessels into which the wort passes in order that it may be rapidly cooled before being admitted into the fermenting tun. Such coolers are generally constructed of wood, and occasionally of iron, but the best of all are of copper; if of wood, all the architect has to provide are the main bearers about 8 or 10 feet apart, all the cross bearers or "under-ribs" forming part of the cooler; if of iron, girders must be inserted as most convenient, with cross girders not more than 2 feet apart, as the cooler plates should not be more than 2 feet square; if the coolers are of copper, then girders where most convenient with wooden cross bearers not more than 9 in. apart, but in no instance should the copper be allowed to come in contact with the iron, as a galvanic action would ensue. The coolers should be laid to a regular fall towards the outlet of not less than 1 in. in 10 feet. Occasionally coolers have been constructed of brick arches, turned between iron girders, and the surface covered with glazed tiles; this plan is to be utterly condemned, as the great and sudden variation of temperature they are exposed to, ranging in winter from perhaps 10° to 180° causes an expansion which soon loosens the tiles, and renders it perfectly impossible to keep such coolers sweet. If possible, there should be large openings all round the coolers, fitted with shutters or louvre boards. The description of refrigerator should be ascertained before designing this portion of the work, as some of these cooling machines work in a horizontal, and some in a perpendicular position, the latter requiring at least 4 feet of additional height between the coolers and the fermenting tuns. The tuns are generally constructed of wood, either round or square, but slate tuns are gradually coming into use, the iron work for supporting such tuns should be very rigid, as if the least deflection takes place, the joints of the slate will open, and the vessels will never remain tight. On the floor below the tuns, room must be provided for the cleansing pieces, and if skimming is practised, receptacles for the yeast as skimming off the heads of the tun; again on the floor below these

cleansing pieces, must be abundance of room for filling the casks, or as it is technically termed "Racking." In a convenient and central position should be placed a machine for lowering the full casks into the cellar, and provision will have to be made for the machine for raising the casks to the loading out stage. Occasionally an hydraulic lift is used, and in that case one machine is sufficient for lowering or raising.

Occasionally, but now very rarely, vats are required for storing beer: these vary in size from 10 to 2500 barrels, and are made of oak: the bottoms should be at least 3 ft. 6 in. from the cellar floor, or better still supported on iron columns and girders, so as to leave sufficient head room for the cellar men to work beneath them. It has been urged by some theorists that the use of iron framing is to be condemned, on account of its being such a good conductor of electricity, and as is stated by Black "it has long been "the opinion of many eminent chemists, both English and French, that electricity is a powerful agent in "fermentation, as well as in preserving or destroying beer." But judging now from the almost universal use of iron throughout breweries, the objection appears to be more theoretical than practical. At the same time, from the various observations that have been made, it appears to be highly objectionable to sink any vessels in the ground, as in such a case, certain unfavourable agencies from time to time manifest themselves, which can only be attributed to electricity acting upon the beer.

It is very often advisable to excavate for vaults under the yard or open ground, if so, there should be a considerable depth of earth over the crown of the arch, as many vaults, in every other respect all that could be desired, are rendered utterly useless for storing beer in during the summer months, in consequence of this not being attended to, the sun beating down on the paving above, and raising the temperature to too high a degree. As far as possible all floors should be constructed fire proof, and are best finished with asphalte, as in consequence of the continual washing the various vessels are subjected to, the floors are being continually wetted; again, asphalte stands the wear of the casks better than any other substance, as York paving is very liable to get chipped and broken by the "chimes" of the casks; another great advantage of asphalte is, that as there are no joints, there is no chance of any beer or waste finding its way into them and there putrifying, and giving rise to any objectionable odours which would be exceedingly damaging, especially while beer is fermenting, as in that state it is so very susceptible that as has been stated by one of our leading brewers, even "striking one of the old lucifer matches over a tun, is sufficient to give "the whole gyle a flavour of sulphur." In the cellars, if iron trams are laid for the casks to roll on it will be sufficient to fill in between with cement concrete.

The roofs are best covered with tiles, as on account of their porous nature any steam or moisture coming into contact is not condensed. When slate is used, the continual dripping from a slate roof becomes a constant annoyance. The ventilation of all parts should be well considered, as abundance of fresh air is wanted in every part except the hop and malt stores, which cannot be too close for the reasons before given. It may seem a small matter to mention, but care should be taken in arranging the stairs, for, as many of the men wear clogs, and so much water being used about the brewery, accidents are liable to occur if the stairs are inconvenient. Ample provision should be allowed for getting in the raw material, casks from the cooperage, for loading out the beer, grains, spent hops, &c. Space may have to be provided for machines for drying the grains: these should be placed convenient for the mash tuns and boilers: also for presses for pressing the hops, which should be placed contiguous to the hop back; presses for pressing the yeast, for extracting the small portion of beer the yeast contains, such presses should be placed convenient for the fermenting tuns, and in a good light. No brewery can now be considered complete without an ice making machine, or at least, a machine for cooling water, as with an unlimited supply of water at a very low temperature, say, 408, brewing can be carried on all the year round.

From my experience I have found the cost of a brewery building, will range from *2d.* to *6d.* per cubic foot. A 63-quarter brewery and malting cost about £12,000, or *2d.* per foot. A 24-quarter brewery, brick built, cost £3,600, or $4\frac{1}{4}$*d.* per foot. The buildings for a 100-quarter brewery carried up in stone, not including the tun room, cost about £5,400, or $5\frac{1}{4}$*d.* per foot. A 40-quarter brewery of brick, with a considerable amount of moulded brick dressings, &c., £3,700, or *6d.* per foot. These amounts include the setting for the coppers and boilers and chimney shafts. The total cost, including the plant for the 63-quarter brewery, and a 70-quarter malting, was about £20,000: a 24-quarter, total cost £6,300, or £262 per quarter. A 40-quarter brewery complete, costs about £8,900, or £225 per quarter. A 100-quarter without tun rooms, costs about £9,600, or say £100 per quarter. A 24-quarter £7,700, or £320 per quarter. These amounts do not include the cooperage department. Now as a rule, a brewery cooperage is only required for repairing (not making) casks, and should therefore be of a greater width than a shop where casks are to be made; about 20 feet in width will give a very convenient shop. Each man will require to have a wood block, and an iron plate let into the floor for placing the casks on, when driving the hoops, and one or two commodious firing places for firing the casks in; these should be about 6 or 8 feet square, and covered with an iron hood, having an outlet not less than 2 feet square at the apex. The floors should either be of oak plank or wood blocks, as ordinary street pavement. The hearths of the firing places may be paved with brick on edge, as they stand the heat better than any other description of pavement. Over the shops should be a good loft for the storage of flags, hoops, &c.

In the yard it will be necessary to arrange for two or three troughs or "stillions," for steaming and washing the casks on; occasionally it is necessary to have a separate small boiler for heating the water, and supplying the steam for this purpose.

Stables will also be required, but there is no occasion for me to say anything on that head.

Having now considered the brewery, we will pass on to the maltings.

Compared with brewing the process of malting is exceedingly simple. The raw barley has first to be steeped in water in the cistern until the grain is thoroughly soaked, it is then thrown out on to the couch where the grain commences to germinate. At a certain period it is spread out over the working floors, and when the growth has reached the right stage it is thrown on to the kiln, where it is dried, and the malt is then ready for the brewer. A malting should have a large store on the top floor for barley and for malt. The barley store, according to the Excise regulations, must have a separate entrance from the yard or street, as no communication is allowed between the barley and malt lofts. The roofs over such stores should be close ceiled, and the stores as air-tight as possible. The barley store should be directly over the cistern, so that it can be lowered into the cistern without any labour. Maltings have either one, two or three floors, according to size, which floors should be rectangular. The cistern can be either of cast-iron or brick, rendered in cement, and rectangular in form. Down the centre of the bottom must be a drain covered with cast iron perforated plates to drain off the superfluous moisture. According to the Excise regulations the cistern must be rectangular. The depth must not exceed 40 inches, and there must be a clear space of 48 inches over it, and must be well lighted, in order that the Excise officer may be enabled to take the guage readily. The usual allowance is $12\frac{1}{2}$ cubic feet per quarter. The couch should adjoin the cistern. Here, again, the excise regulations must be strictly attended to. They are as follows: The couch must be rectangular; the depth not to exceed 30 inches; one side and the two ends must be permanent (usually carried up in 14 inch work), and cemented on the inside, the front moveable, and must consist of boards not less than 2 inches thick, and so arranged as to be strictly rigid when the couch is charged, as if it bulges in the least it cannot be guaged accurately. If the malting consists of two floors, the cistern and

couch are best placed midway between the two, so that the men can throw the malt on to either floor without much labour. If of three floors, then they should be placed on the middle floor. The usual allowance for the working floors is from 180 to 200 square feet, for every quarter, rectangular in shape, and never exceeding 40 feet in width. Many different descriptions of materials have been tried for forming these floors, but the floors most approved of now are of cement either on rough boarding or the best concrete arches turned between rolled iron joists, the floor being finished in Portland cement to a perfectly true and level surface. Not much light is required for these floors, and opinions differ whether the openings should be glazed or not. Occasionally the openings are glazed with blue glass, in order to subdue the light and assist the growth of the corn. But the general practice is to fit the openings with sliding shutters, having a small pane of glass in the centre, with a shutter so that the light can be totally excluded at the pleasure of the malster. It is a good plan to have a skirting of four courses of hard clinker bricks round each floor, for if the ordinary bricks are used they are liable to be much damaged by the shovels of the men when turning the malt over.

The kiln for drying should be situated at the end of the working floors, opposite to the cistern, the arrangement of which must depend on the quality of malt to be made. If very pale malt is required, the drying floor should be from 17 to 20 feet above the level of the furnace bars; if malt for porter, then 10 or 12 feet will be sufficient. The drying floors are of various descriptions, being constructed either of hair cloth, woven wire, perforated iron plates, or, best of all, perforated tiles, which are made expressly for the purpose about 12 in. square, and about 1¼ in. thick. The manufacture of such tiles is carried to a great state of perfection by Messrs. Fison, of Stowmarket. Great care should be taken that all the tiles are set perfectly flush, for if one projects only a trifle above another it makes it very awkward to shovel the malt off the kiln floor. The usual allowance is from 20 to 25 ft. super for each quarter, the latter for pale malt. The object to be attained in drying is to perform the operation as rapidly as possible. To effect this there must be a large body of hot air passed through the malt; therefore the opening to the firing place should be ample, and closed with sliding iron shutters, so that the inlet of cold air can be regulated according to circumstances. The furnaces are either fixed or moveable according to the opinion of the malster. But under any circumstances there must be fixed a spark floor or heat distributer immediately over the fire, which is best constructed of fire tiles supported on light iron bearers, the object being to prevent the heat from the furnace striking the drying floor in one particular part, and so rendering the drying unequal. The roof over the kiln can either be finished with a ventilator running down the ridge, fitted with louvre boarding on either side, as most of the Burton kilns are, or with cowls, the latter arrangement being generally considered the best, as any slight change of wind will not affect the regular drying. The best cowls are now made of light copper, the first cost is not much in excess of wooden ones, and in the end much cheaper. The roofs generally should have a steep pitch, and may be slated. The height from kiln floor to base of cowl varies from 20 to 30 feet. It is best to carry up the walls at least 5 feet above the floor, so as to enable the men to work comfortably on all parts of the floor. The underside of the rafters should be lined with match-boarding, secured with copper nails, as this stands better than lath and plaster, there being a considerable amount of moisture given off when the malt is first placed on the kiln floor. There must be some arrangement for hoisting the malt from the kiln into the loft, which loft is best fitted with deep bins, such as described when speaking of the store in the brewery.

These then are my views as to what a brewery and malting should be, and by way of conclusion I would urge upon any one who may be engaged to carry out any such work, to have the intention of the proprietor very clearly expressed in writing, as to the system upon which the brewing is to be conducted; in general it is a difficult matter to get definite instructions as to the many points of detail, and it is

always advisable to get the brewer's authority in writing, confirming any particular form of apparatus which may be proposed to be introduced, and it is as well to get the notions of the gentlemen who may have to work the plant, as many a valuable hint may be thus obtained as to small matters of detail, which would otherwise be overlooked until the deficiencies were found out when commencing to work the plant, thereby causing a long bill of extras to the dissatisfaction of all parties.

THE CHAIRMAN.—Gentlemen, after hearing the clear and exhaustive essay of Mr. Scamell—clear and bright as the liquor ought to be to which it is devoted, we may almost regard brewing as a fine art. Mr. Scamell has described the appliances and manipulations of the raw materials in an interesting and intelligent manner. I have no doubt there are some gentlemen present who may be able to give us some additional information on this subject.

MR. ROUMIEU, Fellow.—I should like to be informed in what way they apply the raw barley as a mixture with the malt. I believe it is common to use a larger quantity of raw grain than malted barley, and that the action of the malt is to turn the raw barley into sugar.

MR. SCAMELL, Associate.—According to the excise regulations, the Government will not allow the raw grain to be mixed with the malt, because there is a duty upon malt, but there is none upon raw barley. The barley and malt stores are obliged to be kept quite separate, with a separate entrance to each.

MR. WYATT PAPWORTH, Fellow.—Allow me to ask whether sugar in contact with iron does not produce a deteriorating effect upon the metal. I have heard that the iron of vessels used for the transport of sugar has become affected from some such cause. I would also ask Mr. Scamell whether he has ever observed the effect of a kiln catching fire—how high the flame from the malt rose? because we know kilns are sometimes burnt down. I noticed how in one of the maltings described the walls are raised five feet high, that no doubt is a convenience in working, and may obviate the danger of the malt catching fire.

MR. SCAMELL.—With reference to storing sugar in iron vessels, all I alluded to was the vessel for dissolving the sugar before it goes into the coppers. There is an iron vessel fitted with a steam coil to dissolve the sugar. As the sugar comes over in bags it is stored in the malt or hop stores, and in that case it is in contact with wood. With regard to the burning of the roof of the kiln, I have never known an instance of such an accident. If the floor is perfectly laid I do not think it very possible, especially as for pale malt the floor is 20 feet above the fire. The only case of malt catching fire I imagine would be from one of the tiles of the floor falling down, malt dust being almost as inflammable as gunpowder. The walls were raised five feet merely for convenience of working.

THE CHAIRMAN.—There is one question which strikes one, and that is the wide difference of price, viz.:—from 2d. to 6d. per foot: and that does not appear to be dependent upon the size of the building, but is I imagine influenced by local circumstances, whether stone or brick is used, and each procured in the neighbourhood of the work. I apprehend there is no reliable figure to be fixed as the cost of breweries.

MR. SCAMELL.—It is hardly fair to take the example of 2d. per foot, which is the lowest, as that building included a large vat store, 130 feet long and 20 feet high, and that was a mere shell. The highest price was in the case of the brewery in Essex, which came to 6d. per foot. One I have in hand near Burton will cost about 3d. per foot. In the case of the higher cost the materials had to be carted two miles from the railway station, which tended to increase the cost.

MR. T. MORRIS, Associate.—I beg to add my testimony to the satisfaction which this paper has afforded us. The subject is interesting to us as architects, and perhaps in former days would have been more so, because then almost every moderately sized house had a brewery of its own. Now only very

large mansions have breweries attached to them, but that is still the custom, and it is there I suppose the best and brightest of beer is brewed. In such cases the architect is thrown upon his own resources, and information of this kind is of the greatest possible value and of the most reliable character. It is quite possible to reduce these plans to the necessary scale you require. Instead of several thousand licensed brewers in old times there were but few. I think the arrangements shown are most valuable, and they enable an architect to reduce them to the scale of his own requirements. I feel great satisfaction in bearing my testimony to the value of this paper.

On the motion of MR. ROUMIEU, seconded by MR. HADFIELD, a vote of thanks was passed to the author of the paper.

THE CHAIRMAN expressed his regret that the interest of the subject had not been enhanced by some information with regard to the German and Dutch systems of brewing, which he had hoped would have been supplemented by a gentleman who had passed many years in Germany, and who he had hoped would have been present on this occasion.

MR. SCAMELL having acknowledged the compliment paid him, said: the only difference I believe between the German and the French system is after the beer is admitted into the fermenting tuns. In Germany it is done by bottom fermentation at a low temperature, and the fermentation is carried on for many days, whereas in England it is rapidly done. The French brewers are for the most part dirty in their process of manufacture, whereas with all successful brewers in this country cleanliness is the great point of the establishments. All pipes should be very accessible for the purpose of cleaning out.

The discussion having then been brought to a close, the meeting adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, 19th February, 1872, the following Papers were read—HORACE JONES, Vice-President in the Chair:—

THE LATE EDWARD WALTERS, ARCHITECT, OF MANCHESTER.

MR. E. I'ANSON, Vice-President, said:—Gentlemen, I claim the sad privilege, as a near relation of a late able architect, to give in this meeting of his professional brethren, a brief notice of his recent and premature death, and of his professional life.

In the newspapers of the 24th of last month appeared the short announcement: "Died, at Brighton, Edward Walters, late of Manchester, in the 64th year of his life."

Edward Walters was, in the locality in which he practised, well-known—he was a distinguished architect and an honourable man—he was the author of works of great merit and public importance in Manchester, and in surrounding districts. You will not therefore, I trust, feel it amiss, before the ordinary business of the evening commences, that I should give a short notice of his career. He was the son of an architect practising in London, whose professional career was prematurely terminated by death. His father was in the office of Daniel Alexander, where were with him my own father, James Savage, John Wallen, Ashpitel the elder, Whichcord the elder, Busby, and Richard Suter—all of whom, except the last named, have now been removed from the scene of their earthly labours. Edward Walters was left an orphan early in life, comparatively unprovided for, and the struggles of his lonely youth probably account, in some measure, for the retiring habits of his after life. After his father's early death, he entered the office of his father's former assistant, Mr. Isaac Clarke: he afterwards assisted Mr. Lewis Vulliamy, and eventually Mr. (afterwards Sir John) Rennie, by whom he was sent to Constantinople, as architect to the Small Arms Factory, which Mr. Rennie built for the Sultan of Turkey. There he formed, before he left in 1836, the acquaintance of that enlightened statesman, Richard Cobden, who, whilst visiting Constantinople, was taken ill, and having asked for the company of some resident Englishman, Walters kindly tended him in his illness, and thus originated a friendship which lasted until Cobden's death. Cobden invited him to Manchester when his engagement with Mr. Rennie ceased—an invitation of which he availed himself, and was almost immediately introduced into some professional work by his friend. He came to Manchester just at the time when Lane was retiring from practice, but notwithstanding all that his kind and influential patron could do, he had the inevitable struggle of an unknown man venturing into a strange land. In due time, however, his pleasing personal appearance and manner, his high integrity and sense of honour, his ability and unwearied industry enabled him to achieve the distinguished reputation which for many years he enjoyed in Manchester.

One of his first important works was Mr. Brown's Warehouse, in Portland Street, and amongst his

other works are the Free Trade Hall, Manchester, and Salford, Cavendish Street Chapel and Schools, Knot-Mill Chapel, Bank in Mosly Street, Manchester. On the walls are specimens of his drawings, all his own work, but he was assisted in them by his friend Mr. William Wild, an eminent English artist, residing in Paris, particularly in the backgrounds. His last important work was the Assize Courts competition at Manchester, subsequent to which he relinquished his business in favour of his pupils. He was not a member of this Institute, and was of a very shy and retiring disposition. He remained unmarried throughout his life, and mixed little with his professional brethren. He had very warm friends in Cobden, the Agnews, W. H. Barlow, C.E., and others.

MR. EDWARD HALL, F.S.A., Visitor.—I hope I may be permitted to add a few words to what has been already so well said with reference to my late excellent friend, Edward Walters. I knew him from the year of his first arrival in Manchester, when he became a frequent visitor at my father's house; and, with the recollection of the time I have spent with him since, there seems to be embodied the larger portion of my life. He, I consider, contributed, in a very great measure, to that *art* which is characteristic of the buildings or architecture of my native town. Many will feel the real importance of such contribution to architecture, in a city like Manchester, and consequently to the art-architecture of the country; but those who would fully appreciate the service rendered by Walters ought to be acquainted with the progress of architecture in Manchester previous to his time, or from the period of the works of that celebrated man, Harrison, of Chester, who was the first to introduce Grecian buildings in the town, preceding, as he did, Francis Goodwin and Richard Lane. I think Edward Walters did great service in the direction I refer to. He happened to go to Manchester at a most important time. There was a speculative mania growing up, as well as a disposition towards the erection of large warehouses. Warehouses being required, Walters had the ability and readiness to perceive that such structures were capable of being ennobled by the graces of art. The conditions attached to those buildings were very favourable to architectural effect: in particular there was an opportunity for breadth; and in place of mere masses of brick, this architect produced edifices well-proportioned in their storeys and openings, characterized by beautiful features, such as the doorways, and full of details which were not merely novelties, but of great art merit. If you look carefully into these drawings, you will see an amount of industry in the design of detail that is seldom found. Some of Mr. Walters's most successful buildings were in brick and stone; but soon after he got to work, stone at moderate cost became available; and his best-known warehouses are in that material. But it is quite true, as may have been implied from what Mr. I'Anson has said, that Walters was as much indebted to his personal appearance and charming manners as to the appreciation of his talents in art. I think it is very desirable that these reviews of the progress of architecture should be made from time to time in this Institute; and I am sure, whenever due record is made of the growth of art in modern architecture of this country, a prominent place will be given to the name of my late dear friend, Edward Walters.

SOME PRACTICAL HINTS ON HOUSE BUILDING, &c.

By E. Roberts, F.S.A., Fellow.

At the instance of the Committee entrusted with the duty of selecting papers, whose efforts have proved of such value as to make us all feel grateful, and rejoice at the result of their labours, the title of this paper has been altered in order that it should thereby appear to be one of a practical nature. Yet, I venture to say my first title "On some things not generally considered" though not indicating, as the Committee desired, the nature of the subjects, is quite as appropriate as that substituted, and conveyed my meaning better. My purpose is to speak of some very common things which have been in my own practice treated differently from the usual manner, and, from the habit we all have of running in grooves, are usually dealt with as heretofore merely from want of consideration, We fail to perceive that inconvenience is "necessity," and we therefore forget the "mother of invention," till some fine morning we find a new trifle which simplifies some daily proceeding, and then we wonder how it is we have so long done without it. Many in their daily practice have unique objects of use, either lessening labour or rendering work easier, but mostly we run in grooves which are centuries old. That which I hope will be the effect of my paper is that others who adopt varying modes of dealing with these common things will be induced to make us acquainted with them without fear of their being considered beneath our dignity.

My desire to-night is to invite your attention to such subjects as these:—

1. Site, soil, and drainage.
2. Utilization and disposal of water.
3. Artificial lighting.
4. Warming and ventilation.

You will see that we are to deal with earth, water, fire, and air, so that as I purpose to speak of these in their simplest treatment, my paper may in every sense be called *Elementary.*

Firstly then, of earth—*i. e.* site, soil, and drainage. Until last session I was under the impression that I held heretical opinions as regards porous soils, but Professor Ansted's paper on the *Selection of building sites,* (in which he unknowingly took a leaf out of my book,) produced a discussion which at least showed that at that time the medical profession had nearly arrived at opinions similar to those I had formed a great number of years before. I confess to a feeling almost of amusement at the consternation which seemed to prevail at the announcement that the much vaunted gravelly soil was far less healthy than impervious clay. Yet, so it is; and the slightest consideration would lead every one to the same conclusion. That which is required for clay soils is abundance of land drains, which tend to mitigate the humidity, and raise the temperature of the atmosphere. But even Professor Ansted's opinion in the early part of his paper seemed to be in favour of gravel, and subsequently modified by the result of Professor Pettenkofer's observations which were communicated to him after his paper was in type. At p. 50 (Transactions for 1870-1), he says, "Thus, in a general sense, it may be considered as proved by experience that clay soils and other impermeable material near the surface are less healthy than well drained sites, and more liable to attacks of fever, and that permeable soils and gravel are dry and healthy. There are, however, important modifications of this view dependant on the subsoil and underlying rock which are often out of sight and below even deep foundations." And further on, he adds "In certain cases where bands of clay intervene in gravel, the *presence* or absence of fever in the population of a town corresponds exactly with the *existence* or otherwise of these impermeable

deposits." At page 52 however, we find the following remark, "Since this memoir was in type, I have obtained from my friend Dr. Letheby the pamphlet by Dr. Pettenkofer, already alluded to, in which attention is drawn to the great influence of subsoil and rock on certain diseases, especially cholera and typhus. Dr. Pettenkofer points out that in the case of Gibraltar and Malta it was proved by British statistical returns that at a time when cholera was raging over a large area, there were certain small localities that escaped. On investigation it was found that, whereas the subsoil to a great depth, and in the case of Malta, the rock also was eminently porous and permeable, the spots that escaped were situated on impermeable clays." Yet as regards gravels, having said that they are "dry and healthy," he properly and accurately says at p. 51 "It is now well known that however pleasant clear spring water may be to the taste, it is capable of containing and does in certain cases contain injurious ingredients sufficient to render it a fatal poison. There can be no doubt that certain superficial deposits and certain rocks are liable to induce this state in the water, while others are not." And further on "Absorbent gravels resting on non-absorbent rocks may be expected to introduce poison into water when the ground is liable to be covered with decomposing animal or vegetable matter, or with sewage, for the rain entering them cannot fail to carry in water loaded with as much of such impurities as it can contain."

Having resided* in the gravel valley of the Thames, I can bear witness to the facility of the passage of water, which caused me a second and undesired cold bath one Sunday morning while on my way to the underground wine cellar.

Few subjects can be more important than this to the architect who is engaged on country buildings, as on him devolves the duty of advising on the drainage and water-supply by which health may be retained or destroyed. Recent events in Norfolk have drawn public attention to this subject, but not more than it demands at our hands. Already have we been pointed at as responsible for much that is going on, aud it is more than hinted that we are incompetent to provide remedies. I may I think say that however deeply and wisely some have thought on this subject during their practice it is one that is not generally considered.

The whole question however seems to resolve itself into one of water supply, for if we eliminate from it the one subject of drinking-water, it seems comparatively harmless so long as pernicious exhalations or poisonous effluvia can be prevented. In this view it may be said that while drains in clay soils *may* be laid dry with comparative impunity, those in pervious soils should be perfectly water tight. In truth however every drain and sewer should be impervious.*

Assuming therefore that the mere preventing of evils from these causes is easily within the reach of all, the matter of domestic water-supply would seem to be of the greatest difficulty as well as importance. Well-water should be rigorously excluded unless it can be procured from pure mountain sources or from deep wells free from polluting causes, and here again I may properly quote Professor Ansted, p. 51, "Land springs and artesian springsfrom basins are dangerons. Springs from hill sides or artesian springs reaching water tapped in its progress to an outlet are generally safe."

Who does not remember the reputation of the Aldgate pump? pure sparkling water to the sight, but fraught with such evils as eventually caused it to be closed. The subject reminds me of an expression used by an inhabitant at Swindon during an enquiry on which I was engaged. Swindon it may be known is on high land, with alternating layers of pervious and impervious soil, and as wells and cesspools existed at that time in every separate holding, it was emphatically and truly said that "every man's cesspool drained into his neighbour's well." That state happily no longer exists, but its fatal effects I well knew. In my practice I have invariably kept all drains outside dwellings, impervious, and removed from water supply.

* See Dr. Letheby's observations, pp. 53—54, as to the influence of impervious soils on zymotic disease.

Water therefore should be drawn from the least contaminated sources. And is it too much to say for London, bearing in mind the pure supply for Bristol from the Malvern Hills, and for Glasgow from Loch Katrine, that, whatever the cost, London should be supplied from some equally pure source even if from Loch Lomond or the Bala Lake, Westmoreland or Cumberland, whose waters are freer from impurities than any pastoral or cereal districts?

In reference to the second section of my subject—the utilization and disposal of water—I may state that it is by no means uncommon for us to leave plumbers and other workmen to do as they please, and therefore for want of consideration we have supply-pipes to closets inserted in the same cisterns whence water is drawn for drinking purposes; soil pipes arranged so that they convey sewer-gas into the dwelling, and waste pipes from wash basins and sinks carried into closet traps, and although in the last case intermediate traps may be fixed, yet every time the closet plug is drawn the draft on the pipe empties the trap and allows the foul air to escape through the pipes into the rooms. Mr. Seddon and others have taken up the subject of sewer-gas. In the other cases the apparent remedy is either to have separate cisterns for the supplies for the several purposes, or to have partitions placed in such a manner that the drinking water cannot be contaminated; and in reference to waste pipes to carry them down separately into pipes free from sewage-gas. In cases where supplies are by heads of water, whether by public companies or privately, if the water be stagnant in the pipes, freezing and bursting are the consequences in cold weather. The remedy appears to be to have the supply pipes laid with a general fall towards the mains, so that when the pressure is taken off, the pipes may be emptied by gravitation; and, disregarding companies' directions, to tie down ball-cocks to allow the flow to continue while the pressure is on. The straw bands which show distress in winter might then be dispensed with. In the case of unintermittent supplies, there seems to be no other method than packing with saw-dust or hay-bands.

Rain-water in the country is of prime importance, but is usually a cause of much labour and expense, first to conduct it to tanks, and next to pump it to the places where it is wanted. I am unaware if any one has given a thought to this subject, except as to the form and ornamentation of gutters, pipes, and heads, and the description of force-pumps. I have found it more economical to provide for the water remaining where it falls, at the top of the building. I thus save the expense of the down pipes and tanks, the pumps and rising mains, and, what is of far more importance, I avoid the labour of pumping it whence it came, and every one of us must know how great is the time and force engaged in that operation in country residences. I produce one or two plans where the cisterns are introduced in the roofs for rain-water. In that of Christ College, Finchley, not an ounce of the rainfall is allowed to escape; it is directed to a series of cisterns which supply the upper lavatories; an overflow supplies a second cistern, whence the lower lavatories are served. Should these not contain the whole of the fall, it overflows to a tank in the basement, it being desirable to retain as much as possible. The cisterns contain over 9000 gallons, and the tank 1500 gallons. In the tower is a cistern for hard water which supplies the closets, and in times of drought the rain-water cisterns can be filled from the tower, but in only one season since its erection in 1860 has it being necessary to draw largely upon that source. I have invariably adopted this principle wherever possible, and I find it universally satisfactory.

It may be worth consideration how far the steam injector can be made available for filling cisterns. I have only once made the attempt, but abandoned it on account of the position of the cistern precluding the application of the injector, because of the water, when elevated, being also raised in temperature: the steam arising from it is objectionable, and the boiling would perhaps tend to limit the use of the water itself. In factories it would appear to be perfectly admissible.

Although I have been referring to rain water in the country I am not sure that its use need be limited to rural districts. The storm-water in towns is a difficulty; perhaps if rain-water were to be stored it would obviate some of the troubles of sewer construction, and provide means for flushing in exceptionally dry seasons. The rain-fall on roofs in London for instance is probably one sixth of the whole area; quite enough to make a sensible difference in the contents of the sewers, which are sometimes ruptured with the internal pressure of storm-water.

I pass now to the third part of our considerations—artificial lighting.

I am alive to the difficulties of the subject, and to the impossibility of saying any one thing authoritatively which may not prove in other cases to be wholly untrue and inapplicable. I suppose it will be generally admitted that, as regards natural light, a skylight (except for very special purposes) is the worst light that can be adopted. It produces shadow from the person bending over any object; it causes cold in winter by the vertical radiation, and heat in summer by direct rays:—indeed, except where other light cannot be obtained, it is indefensible.

Admitting this, who will say so of artificial light? That it is inconvenient if placed over-head is certain, and not one of us but has felt the discomfort of such a light, and shifted our chairs in order to avoid the shadow of either head or hand—and yet we constantly adopt it. Does it never occur to us that whereas side-light in the case of day-light is the best and most convenient, artificial light from a similar point is equally proper? I believe that in our offices and libraries alone do we feel (and that I fear without *studying* the subject) that a lamp on our table, near to hand, removable at pleasure, and perhaps with the light deflected, and the eyes screened by a green paper shade, is approaching the perfection of light for use.

It has always appeared to me that every room should be lighted according to the uses to which it is to be applied:—a dining-room, for instance, should have a brilliant light, but soft on the table itself, with a softer light around the room, so that no part is gloomy though absolutely free from prominence and glare; and, whether candles, lamps or gas be the means, the light should be in the middle, somewhat akin to billiard-table lights, except as to the deflecting shades.

The mention of billiard-room lights induces me to give expression to my belief that although as a rule, no sufficient attention has been paid to other lighting, in that case it is nearly perfection, avoiding, as it does, shadow on the balls and cushions. Direct vertical light in other places may be unbecoming. I well remember the consternation and dismay said to have been caused to the Court beauties on the opening of the new ball-room at Buckingham Palace, and whether true or not, this very fairly illustrates the position I take. The ball-room was at first mainly lighted by sun-burners, and the effect of the shadows from the ladies' brows, noses, and chins were such as to drive those sensitive creatures from the room. Since then candelabra and other lights have been introduced. There is a feeble attempt there to do that which, without knowing of that instance I have frequently endeavoured to accomplish, but have not found my clients venturesome enough to indulge me, namely, lighting by gas outside glass screens in the walls. If windows are the best lights which can be obtained, it seems to follow that similarly placed artificial lights would be best at night. It would probably involve a great expenditure of gas, but the inside would be free from the damaging and uncomfortable effects of combustion.

Many a time has it occurred to me to stand, music in hand, with perhaps a hundred others, beneath a large chandelier in the middle of a huge drawing-room, our faces of course to the audience, who are on the opposite side of the central light, and unable to decipher the programmes except by bending painfully forward. Even in the rooms of professors of music has this mistake been made, and frequently on my suggestion have lamps been placed behind, as well as before, the performers, so as to enable them to read in comfort.

On one occasion I brought this point practically before one of the most eminent civil engineers in the kingdom, for whom I was acting professionally. On his expressing a desire for a chandelier in a particular room—not a large one—I recommended wall-lights; but until I placed all the chairs round the room, with the sitters' knees almost touching the walls, their backs to each other, he could not be brought to see the absurdity of his proposal. I need hardly say that, as the room was for family use, the chandelier was abandoned. The use of gas has brought troubles with it, and the whole subject, even now after fifty years' experience, requires consideration.

We now come to the final item in my list—AIR, and here I am aware I shall be met by every variety of favourite theory and practice. I have, of course, one of my own, but it is not universally applicable, nor even generally so, except with varying adaptations.

Ventilation is not properly understood by the public, and is repressed or prevented in almost every case where provision is made for it, by the papering up of gratings, and so forth. Ventilation to be perfect should be the admission, by the means we provide, of an equal amount of fresh and pure air to that extracted. As self-acting extractors I have frequently adopted Chowne's air syphons in two positions; one near the ceiling, to withdraw the merely heated air arising from gas or other lamps, and the other at the floor level; the latter, invariably in places where large numbers of persons congregate, for the extraction of those impurities which cause discomfort; for, relatively, carbonic acid gas is heavier at equal temperatures, and falls to the lower strata of atmospheres. This must have been experienced by every one in such places as omnibuses with closed doors, and in the old fashioned church pew; in such cases the opening of the door is an immediate relief from headache and oppression, and the drowsiness for which the sermon usually gets the credit.

The admission of fresh air is another matter not generally considered. How constantly do we find gratings fixed in skirtings at which fresh *cold* air is to make its entry, and it takes the opportunity of making itself known by almost cutting off our feet with its keenness, aud rendering the lower limbs sensibly lower also in temperature, causing those catarrhs which we never know how we have caught. On the other hand, warmed air is as frequently admitted from gratings in the floors or through vertical pipes. In both cases the converse systems should be adopted. *Cold air should always be admitted vertically*, and, if possible, at a level above the shoulders of sitters. Cold air thus admitted will ascend several feet without departing from its columnar form. As it is the same with warm air, which when admitted we require at the very lowest part of the room, it follows that it should be *invariably admitted horizontally*, thus ensuring the benefit of its temperature and freshness, instead of receiving it vitiated, after it has been up to the top of the room.

Again, every kind of ventilation—that is, inlets and outlets, cold and warm, self acting and forced, should be always by tubes.

I have mentioned the air-syphon, which I have usually found most efficacious, although not always successful. It is an inverted syphon, and is founded on the ascertained tendency of air within tubes to move upward, owing to the naturally greater temperature of air within shafts or tubes. In the course of many years' experiments in this and collateral subjects, it comes to be found that zinc is the material which causes the greatest volition—in other words, more readily rarefies the air within it—and glazed earthenware the least: indeed, in the latter, the tendency is rather the other way. I know of two cases where glazed pipes have been used for chimney flues, and they are signal failures.

I promised that I would speak of very common things, and I have fulfilled my promise in that respect. I desire, however, in concluding, to ask you not to allow the impression to be on your minds

that I lay claim to any exclusive knowledge. I merely give some practical hints, which I trust may be useful to some, and which in some respects I believe to be original.

I may summarize what I have said by stating negatively :—

1. Never allow pervious drains in pervious soils.
2. Never allow a cesspool or drain near a well.
3. Never select gravel as a building-site if well-drained clay can be obtained.
4. Never allow drinking-water to be drawn from a cistern supplying a water-closet.
5. Never allow waste-pipes to be inserted into water-closet traps.
6. Never allow rain-water to run to the ground if it be required above.
7. Never allow water to stand in exposed pipes in frost.
8. Never allow pipes to be fixed so that they will not empty themselves.
9. Never ventilate except by pipes; inlets and outlets being equal.
10. Never use glazed earthenware pipes for upward flues.
11. Never allow chandeliers to be the exclusive light merely because it has been customary.

Mr. ROBERTS having thus concluded his paper, the Chairman Mr. HORACE JONES, V.P., said.—You have all heard this charming little essay of our friend, not the less charming because a great deal of wisdom and good sense is contained in a short compass. I have no doubt there are many gentlemen here who will contribute their quota of knowledge and express their opinions on this subject, and I am sure we shall all listen to them with great pleasure.

Mr. OLIVER, Fellow,—I think Mr. Roberts is mistaken in his remarks about Aldgate pump. It has been removed farther westward, and is still in its full glory; and when the hot weather comes we shall, no doubt, see the omnibus drivers refreshing themselves with a glass of pure water instead of bitter beer.

Mr. JOHN P. SEDDON, Fellow.—I quite approve of almost all Mr. Roberts has said on the practical points which he has brought before us. A good deal more might be said upon most of them. Perhaps the most important one, and that which we might do most good by discussing, is the method of lighting by gas: certainly it has puzzled me more than anything. I speak of getting rid of the products of the combustion of gas. There is a large amount of such in this room at the present moment, by which the air is vitiated, and that near the ceiling is in a state, probably, worse than the atmosphere within the sewers. How is that to be got rid of? The best plan I know is the ventilating gaselier adapted by Hammond of Chandos Street, and others, which I have tried in my own house, and I have found it very valuable, though it is somewhat costly to introduce, and occasionally gives trouble. But the result in conducting completely away the pernicious products of the combustion of gas, and giving a good light, almost without heat, is cheap at any cost. I believe, however, that plan is hardly admissible according to the Building Act, because the pipe is carried up from the gaselier to the chimney flue through the floor. There is certainly great heat passing up that flue for a portion of its length, and hence the supposed danger to the woodwork which, though not in contact, is in close proximity to the outer one of the two iron pipes, one within another, used for the purpose named. On investigation, however, I found that the main difficulty in the system does not arise from the heat, but, paradoxical as it may appear, from the cold; because, so long as the pipe remains hot it performs its office and remains sound, and I have never found the woodwork around it to have suffered; when, however, the pipes have lost the heat, they succumb to another influence, and become corroded by the moisture of the vapours they are conveying: not less than about half a pint of water in an evening is thus condensed within the part of the pipe furthest removed from the gas, that is about a length of six feet

from the chimney flue. From this cause I have found that portion decay, often very rapidly, the metal falling away like tinder. I at first thought that was owing to the heat, and was alarmed for the result, but I found out that this was not the case. The pipes have a downward inclination given them, in order that this water may be conducted to the flue; still the moisture produces the effect that I have described, and no material has yet been found to resist the cause of decay, and perform the duty required of it. Extreme thinness seems requisite in the inner tube, to prevent the abstraction of heat, for which that pipe is suspended inside the larger one, with a free space around it. Glass, though suggested, would, I fear, be too liable to fracture. I hope the difficulty will soon be surmounted, as, with some modifications, this method of dealing with gas deserves much consideration.

With respect to ventilation, it seems to me Mr. Roberts is quite right in saying the best position to bring fresh air into a room is about the height of the head in a vertical column; but it is generally difficult to do this in habitable rooms. You cannot cut off a corner and introduce a pedestal where you like, and if you bring in the air at the lower part of the room it goes direct to the fire-place, and causes draught, although this may be prevented by guarding the inlet with fine wire gauze. My practice is to bring it in near the chimney, taking care that the inlet is not so placed as to feed the fire directly with the air, which it has a natural inclination to do. Gratings above the fireplace opening, communicating with spaces to warm the air in its passage behind or at the sides of the grate, will effect this, as also openings above or at the sides of the chimney-piece. These, if guarded by wire gauze, will allow the air to issue without draught, and it spreads gently, causing genial warmth throughout the room, and rendering it unnecessary for the occupants to crowd round the fire-place.

I might say much about other points which Mr. Roberts has touched upon, as drainage, &c., but as I am engaged in collecting and endeavouring to systematize information upon them, and shall shortly give the profession the results in another form, I will no longer occupy your attention on the present occasion.

Mr. F. P. COCKERELL (Hon. Sec. For. Corr.)—With respect to air brought in close above the fire I have had occasion to try it. I put in several of the stoves made by Boyd at the Freemasons' Hall, and at the time it was being done it was predicted that all the air would go up the chimney. This rather startled me, and I tested it by putting small scraps of very thin paper before the delivery grating, from which I found that the air did fairly rise into the room. Perhaps the best test of all was that the mantel piece being nearly flat, and consisting merely of a moulding of $2\frac{1}{2}$ or 3 inches projection over the fire place, so that it was completely shaded from the fire by the face of the stove, that part which was so protected got hot sooner than other parts more exposed to the fire. No doubt if you admit the air cold it will go to the fire, but if the air is sufficiently heated to give it an upward tendency it will escape the fire and ascend into the room, and come back in the natural way.

Mr. SEDDON.—I think that is the best position to bring in air. In my own fire place the chimney piece is blackened over the opening, so that a good deal of the air does rise.

Mr. C. BARRY.—I think Mr. Roberts' observations have been misunderstood. I gathered that he advised that cold fresh air should be admitted into the room vertically, and warm air horizontally, theory with which I entirely agree, and which I think commends itself to the judgment at once. That cold fresh air, admitted in the ceiling of a room, will sink by natural gravitation through the hot and vitiated air of the room is evident, and that has been tested over and over again by experiment, and unless the difference of temperature is too great, causes no unpleasant sensation. The explanation of the stove described by Mr. Cockerell acting properly, is to be found in the fact that the fresh air admitted by the side of the stove would be warmed first, and becoming rarefied, naturally ascends in the apartment. If cold it would probably have gone directly to the fire. Some experiments were many

years since made by Faraday for the ventilation of the House of Lords, and were of particular interest. It was there found in that chamber, which is 45 feet high, that air admitted at the ceiling only $3\frac{1}{2}$ degrees colder than the air a little above the floor, would reach the floor by the action of gravity, and being presently made use of by the occupants of the room, and thereby heated, would ascend again. The difference of only $3\frac{1}{2}$ degrees of temperature between the inlet channel of air and the outlet caused the colder air to descend 45 feet before it went up again.

There was one opinion given by Mr. Roberts which surprised me, and with which I cannot myself at all agree, viz :—his own preference for building sites on clay soils rather than gravel. I think he is wrong in this. From my own experience I consider the general preference for gravel sites is well founded. I have lived on clay soil, on some of the highest ground of Sydenham Hill, and therefore had opportunity of observation, and all I can say is that although on the ridge of the hill, owing to the continual drainage, there is a very high health-rate; on the slope and at the bottom of the hill on either side I understand the health-rate is not so high, and the reason of that I believe is, that the impervious clay soil is not drained to the same extent in the valley as the higher part of the locality, and thus allows damp exhalations to arise prejudicial to health in many cases.

Mr. E. I'Anson (Fellow).—As a matter of form, I beg to propose a vote of thanks to Mr. Roberts for his paper. On the first point, to which our friend has alluded, viz. the question of soil, I agree with Mr. Barry that it is of little consequence whether it is sandy or clay, if it is well drained. The *rationale* of the matter is this :—The springs of water are all collected on impervious soil, and all come from pervious soil. These springs, except in the chalk, result from the accumulation of water on spongy or porous surfaces, such as sand or gravel, and when it reaches the subsoil it is held in basins of argillaceous matter which retain the moisture; and these basins are almost always basins in the clay soil, holding the water which falls on the surface in the shape of rain, and forming the springs which we have in wells, if we drain from the bottom or on the surface as springs when they are overcharged.

If, as in the gravel of London, the pervious stratum is not very deep, and the area from which the water is derived is contaminated by a large amount of decaying vegetable and animal matter, then the wells do not contain pure water; and with regard to what our friend says about Aldgate pump, I am disposed to think that the Aldgate water is not by any means uncontaminated. Water passing through gravel is mechanically purified, and hence nothing can be brighter and clearer than the water of the London wells, and if it were not for the surface infiltration of impure matters to which they are subject, they would be quite pure.

When water is derived from the lower green sand, such as at Tunbridge Wells, and between this and Portsmouth, near, for example, to where the new Charter House school is built, and which sandy soil extends over a large district, where you have wells 150 feet deep, and get the water which falls over the pervious surface of the lower green sands, which is a large agricultural district and not over-encumbered with animal or vegetable matter, it percolates through some hundred feet of fines and, and by the time it reaches the impervious bottom of the basin in which it is held and rises, it has had time to become purified not only mechanically but chemically, and hence the water from the green sand is always of the purest nature. Gravel in a basin which is overcharged with water, no doubt is as deleterious as clay soil which retains the water. If by abundant drainage the clay is freed of the water it contains, it would be as good as sand in a sanitary point of view, but where there are depressions in the surface of the clay the water has no means of running off, and it becomes mixed with deleterious matters, and soon becomes injurious to health: therefore I hold that clay soil, which retains the soil which falls on it, is more or less hurtful to human health.

With regard to the subject of ventilation, on one occasion I consulted the father of our friend Mr. Barry about the ventilation of a school room, and I asked him to give me a few hints on the subject. He replied, "I believe the best ventilated room in London is Astley's Theatre." I asked him why. "Because," he replied, "it has the greatest amount of openings in the roof of any room I know; and if you have plenty of openings in the roof you are sure to have good ventilation." For my own part I don't know a better ventilated room than Merchant Taylors' Hall. I take no credit to myself for that. It is a room about 40 feet high. At the top of the room there is a large projecting wooden cornice, which projects about 2 feet into the room, and between that and the ceiling is a space of about 2 feet. All round the top of the ceiling, above the ceiling, there are numerous perforations in the roof; and in the *quasi* Gothic windows in that hall, at a level of 12 or 14 feet above the floor, spaces are made to open, and so arranged as to turn the draught of air in a vertical direction. When these are opened or shut, as necessary with the large openings all round the top of the room, I don't know a better ventilated room than that. I attribute a great advantage to the projecting cornice where the air comes in. Exeter Hall was ventilated with large openings all round the ceiling above the walls, and the effect of that was that persons sitting next the walls felt the draught of air descending like a stream of water. The cold air fell down to the ground. The effect of the projecting cornice in Merchant Taylors' Hall is to send the cold air into the middle of the room, and it becomes diffused through the room in a very satisfactory manner. I beg to propose a vote of thanks to Mr. Roberts.

Mr. G. AITCHISON (Fellow).—I have great pleasure in seconding the motion, and will avail myself of the opportunity of asking for explanations upon some of the points more particularly alluded to. First: as to the introduction of fresh and warm air and the withdrawal of foul air by means of pipes, instead of through gratings, and also on the opinion expressed as to the superiority of zinc, (which is stated to be the best material) over earthenware pipes, which are stated to be the worst. As flue pipes I know that glazed earthenware pipes are bad, on account of their smooth surface giving little hold for the soot, which is constantly falling.

Several points have been raised with regard to the value of and objections to different soils, but, in my opinion the question of pervious or impervious soil is secondary to that of thorough drainage both as regards the site of the house itself and the land contiguous to it. It is well known that in walking towards evening along a road in a clay country those portions which are drained are free for a much greater time from mist than those which are undrained, and where drained and undrained land, are contiguous, it is curious to observe how certain parts of the landscape look as if bewitched, being enveloped in fantastic wreaths of mist, that suggest a crowd of floating spirits. Every man who is building a house should put an impervious structure over the whole surface of that house, whether the soil is pervious or not. If the drinking water is obtained from the site there can be no doubt that it would be better to have the top soil impervious clay than pervious gravel; for, in the first case, no pollution of the water could take place from surface impurity, while in the latter case it would; but where the drinking water is brought from other sources, it would be better to have a pervious gravel soil, so that if there were leakage from drains it might pass through the soil, and not be exhaled by surface evaporation.

As far as drain-pipes are concerned, if it be necessary to take such elaborate precautions as have lately been advocated for preventing the escape of sewer gas, the drainage should be done with some material more capable of sustaining sudden pressure than these glazed earthenware pipes, and some more perfect method of jointing should be adopted than mere cements, for we all know how difficult it is to prevent the joints at least from being cracked when the earth is rammed round the pipes.

On the subject of ventilation I would mention that there is a celebrated room in the east of London called the "long room," at St. Katherine's Dock House, where every variety of ventilation was tried. It was built about the year 1828, and all the distinguished doctors of warming and ventilation tried their hands at it—Arnott, Walker, Perkins and other gentlemen less known to fame. To the first of those gentlemen the room was handed over for warming and ventilation upon his system, and after him to a succession of others; but the complaints of too much heat, not enough warmth, of want of air, of draughts, &c., were so numerous, the number of clerks who were away ill from these various effects, and the number who took to wear Welsh wigs to protect their heads from cold draughts of air, was such, that the whole of the ventilators were stopped up, the means of warming were withdrawn, and hot water tins were supplied to those clerks who suffered from cold feet. I have had some little experience myself in warming and ventilating, and I must say, as far as I can see, the failures that have occurred in warming and ventilating have arisen from the want of bringing about two things at the same time, viz. a full and proper supply of pure warm air, and the escape of the air vitiated by breathing, and by the artificial light used. In some cases you bring in fresh air, but you do not take out the whole of the vitiated air. You make a division where the foul air should go out and the fresh air come in, but unfortunately the gases will not always take the direction you want; consequently, instead of getting the foul air you get it mixed with a cold current, to be breathed over again. I fancy the best way is to introduce the air warm, and, for an ordinary room, to introduce fresh air to be warmed in a chamber behind the stove, and let it come out about the level of the top of the grate, and have machinery—ventilating gas burners, for instance—to take away at the same time the air vitiated by breathing and the products of combustion; for if you do not supply sufficient air for your fire, then the cold air comes through this machinery and almost puts out the gas, you have a strong draught coming down to the fire, and you find your ventilating business is a complete failure.

With regard to the subject of heated air rising, I fancy in rooms where public meetings are held the carbonic acid gas given off at the temperature of the body, would rise; but where the temperature is very high that would not be the case. In some of the latest built Turkish baths it is found that the only means of ventilating and keeping up the heat at the same time is to allow the foul air to go out at the level of the floor.

Mr. Banister Fletcher.—It appears to me that what I would call the ordinary methods of ventilation have not been spoken of, and also that the great objection has not been pointed out of those systems of ventilations which depend on gaseliers for their action, such as, for instance, Rickett's plan, where the rooms to which such are attached are used by day as well as by night. I have found in the daytime great inconvenience in the way of down-draught result from them, and I know of no plan by which this has been obviated.

In the ventilation of ordinary houses I think it is wiser to deal with the bad air at the top of the room without those elaborate contrivances which some have introduced, and which have more or less failed in their object. I think the best plan of ventilation I have tried is that which communicates directly with the external atmosphere, as, for example, Sheringham's. If the wall on the opposite side of the room also communicates with the external air I use another Sheringham's ventilator, but where this cannot be done, I use a simple wooden ventilator of my own invention having a balance weight, so that it may be regulated at pleasure, which communicates through the floor, and so with the air outside. I have not found the slightest down-draught from the use of either of these ventilators which Mr. Roberts says is certain to occur where fresh air is admitted horizontally. As I rise to obtain information I would ask Mr. Roberts, whether he has found any means of getting rid of the objectionable receiver of the pan closets, from which a nuisance is admitted to arise. Another point is as to

the valve closets, whether Mr. Roberts has met with the same inconvenience as I have with respect to the want of proper action in consequence of the paper and the objection to the retainer. A further point I should like to know, what is his experience with respect to the D trap, and whether he considers there is any foundation for the statement that they are ineffectual to prevent noxious gases rising through them, and if so, what trap he would recommend. With regard to sun lights I have heard great objections made to them under some circumstances. I may mention a case where I had them put up in offices in the City, with the result that the housekeeper could not use the room over for an hour or an hour and a half after the sun light was extinguished, because of the heat created by it.

The vote of thanks to Mr. Roberts having been unanimously accorded,

Mr. ROBERTS, Fellow, in acknowledging the compliment, said: I purposely made my paper very short and comprehensive, and even, if I may say so, as it were epigrammatic. It may be useful in reference to Mr. Barry's observations to draw attention to some remarks which were made at the meeting last year, when Professor Ansted read his paper, showing that facts there stated must really be taken as conclusive against opinions, from whatever quarter they may come. Referring to the observations of Dr. Letheby on that occasion, I find he says this:—"The geological features of a soil are related to many endemic diseases, and to most epidemics. This has been especially observed during the last epidemic of cholera in London. It happened that certain places in the eastern parts of the metropolis were entirely exempted from cholera, while neighbouring places were seriously affected by it; and when the whole of the facts were enquired into, it was found that the character of the soil was essentially different in the two places, showing that it had much to do, on the one hand, with the prevalence of the disease, and on the other, with immunity from it. The City of London Workhouse, in the Bow Road, for example, felt the force of the epidemic most severely, and in the course of three or four days there were no fewer than twenty-six cases of cholera in one set of rooms only, namely the infirmary. In fact, during the interval from the 26th of July to the 4th or 5th of August, there were nearly fifty cases of cholera, and with one exception they occurred in that set of rooms alone. This was a remarkable fact, and when it came to be enquired into, it was found, from an examination of the geological map of the district, that this infirmary of the workhouse in which the cholera cases occurred stood upon gravel, while the whole of the other portions of the building were erected upon brick earth or clay. In a pauper school at Limehouse, with about 400 children, situated in the very midst of cholera that was raging about it right and left, even in the same street, there was not a single case of the disease. When the circumstances of that case were inquired into, it was ascertained that the school building stood upon a thick bed or island of brick earth, and not upon gravel as was supposed: while the neighbouring houses, in which cholera had been so severe, were built upon made earth and gravel." And Dr. Druitt on the same occasion observed, "If we look at a town situated on a porous soil, we find multitudes of human beings contaminating the soil with those pollutions which are soaked up by the ground and usually carried away by the water which percolates the gravelly soil on its way to the nearest river; but when dry weather comes, then it is that what Dr. Letheby says happens—the soil becomes a medium of giving off the most dangerous miasmas, and the soil of the locality being foul and half dry, assumes the condition of an aguish country, which, if not thoroughly drained, had better be left wet than half dry." And Mr. I'Anson may be assured that if water be once charged with choleraic excreta, no amount of filtration—nor even boiling—will purify it again.

In one respect (continued Mr. Roberts) I think the tenor of my paper is misunderstood. I was not alluding to the position of towns, but to the selection of sites for country residences, and to advise the person about to build himself a house to select such a site as may be well drained, or on impervious soil, with the view of obtaining water for household purposes. Towns have their public water-

works, country houses are dependent chiefly on wells; and that being so, the feeling I have is that sufficient consideration has not always been given to the question of the contamination of water from the soil. Mr. Aitchison, though he asked some questions, so agreed generally with what I said that I need not refer to more than the point with regard to zinc and glazed earthenware pipes. Zinc is found by the anemometer to produce the greatest current of any tubes of equal size; tubes side by side—one of iron and one of zinc for instance—connected at bottom, will invariably take the air down the iron pipe and up the zinc one.

The mist referred to by Mr. Aitchison is clearly that which arises from undrained land, and clay even without reference to water supply, should be very well drained before it is adopted as a site. I disagree with the remarks that have been made with reference to bringing in fresh air by the stove, because it passes out again at the spot where it enters. What we require is, whether it be cold or hot air, that it should permeate the entire room, and should pass into the part where we require to breathe it, so that it ought to enter the side opposite to its exit. On one occasion I ventilated a large room to seat 1200 people by what I may call air drains round the room, carried up by flues to the top of the building. The people did not experience any discomfort, because there was none; but a few years after it was thought desirable to line the walls with wood; the apertures that existed before were closed: and then of course I had complaints that the room was badly ventilated. I desire to press that point, and illustrate it by the room we are now in: we are all feeling discomfort, and if the carbonic acid gas could at this moment be coloured, and the outer doors were opened, we should see it pouring down the stairs like a cataract. In rooms where large numbers congregate, the exit of air should be near the floor. If there are two fire-places in a room without other sufficient inlets, the foul air will go up one, and air descend through the other, but in no such case will it supply the individuals in the room with the fresh air they require. Cold air should be admitted vertically.

[Mr. Roberts here illustrated his views by a sketch on the board.]

On the question of containers in closets I would merely say that is a matter I never specify, and the sooner they are got rid of the better. The best apparatus are those with elastic valves. Mr. Seddon referred to the decay of some pipes, I rather attribute that to the presence of sulphur than any other cause, but I do not think he or other gentlemen who spoke appreciated that which I laid great stress upon, viz.:—the admission of the cold air vertically, and the warm air horizontally. It frequently happens that holes are made in the skirting to admit air, cold or warm, and warm air is admitted through gratings in the floor. I thought it my duty to point out that this system is opposed to that which in my opinion should be adopted. The principle applied in the House of Lords is, I think, as nearly good as can be, if the coldness can be only ameliorated before it reaches the heads of the sitters: but I believe the foul air of the House of Commons was extracted through the floor on Sir Charles Barry's principle, and nothing can be better than that.

The CHAIRMAN again rose and said—I have one other little matter to bring before you, and that is to propose a vote of thanks to Mr. I'Anson for his memoir of the life of one, who though he was not a Fellow of the Institute, was a fellow-worker amongst us. I had the pleasure of knowing Mr. Walters, not very intimately, but I met him on several occasions of professional visits to Manchester, and though I had not the opportunity of knowing him to the same extent as Mr. I'Anson, who I believe was a cousin of the deceased gentleman, I am only too pleased to bear my small mite of testimony to his high and good qualities. I am sure you would wish to express your thanks to Mr. I'Anson for the interesting little memoir he has laid before us.

The proceedings of the evening having thus terminated, the meeting adjourned.

THE KOLTOVSKOÏE CHURCH AT S. PETERSBURG.

Fig. 3.

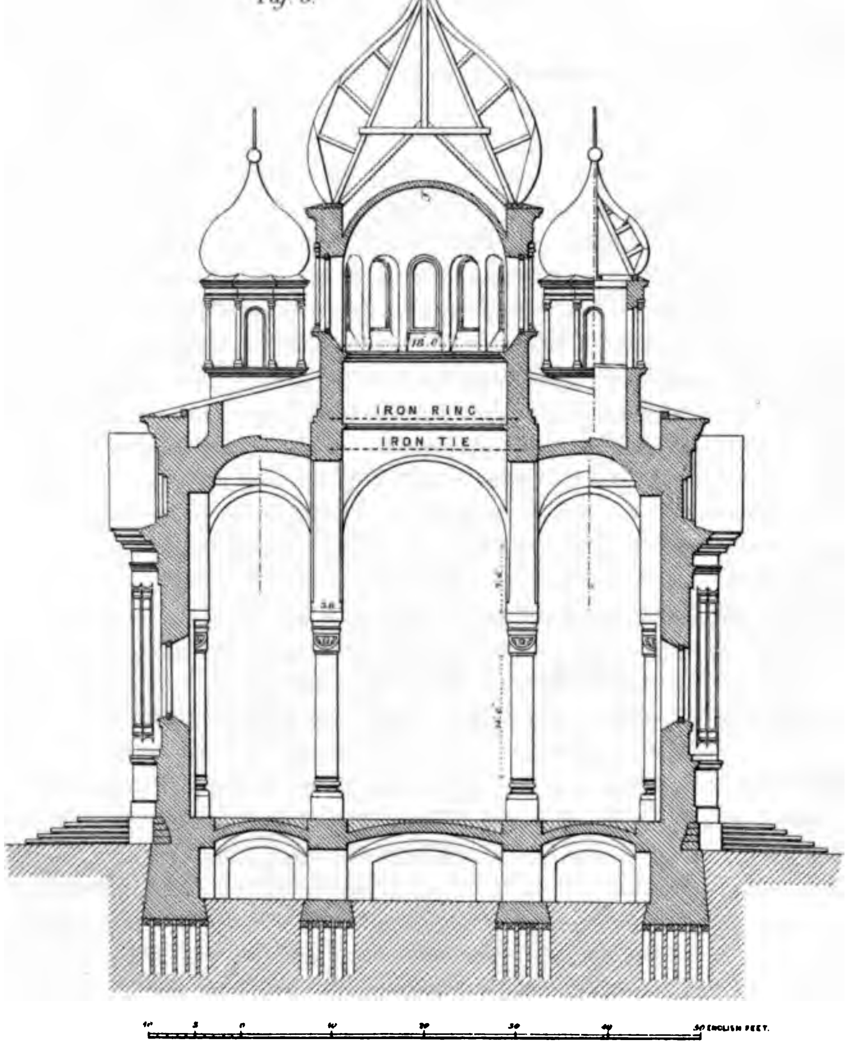
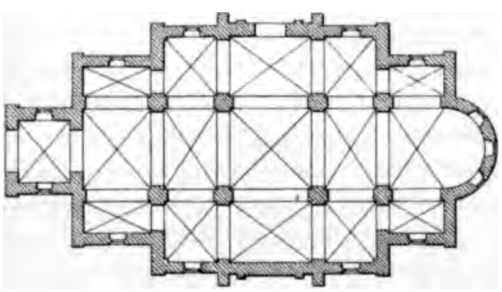
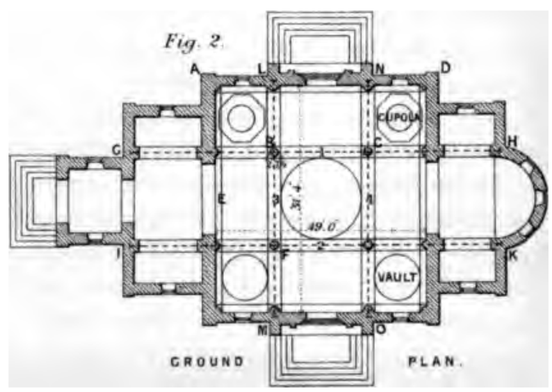


Fig. 1.



BASEMENT PLAN

Fig. 2.



GROUND PLAN.

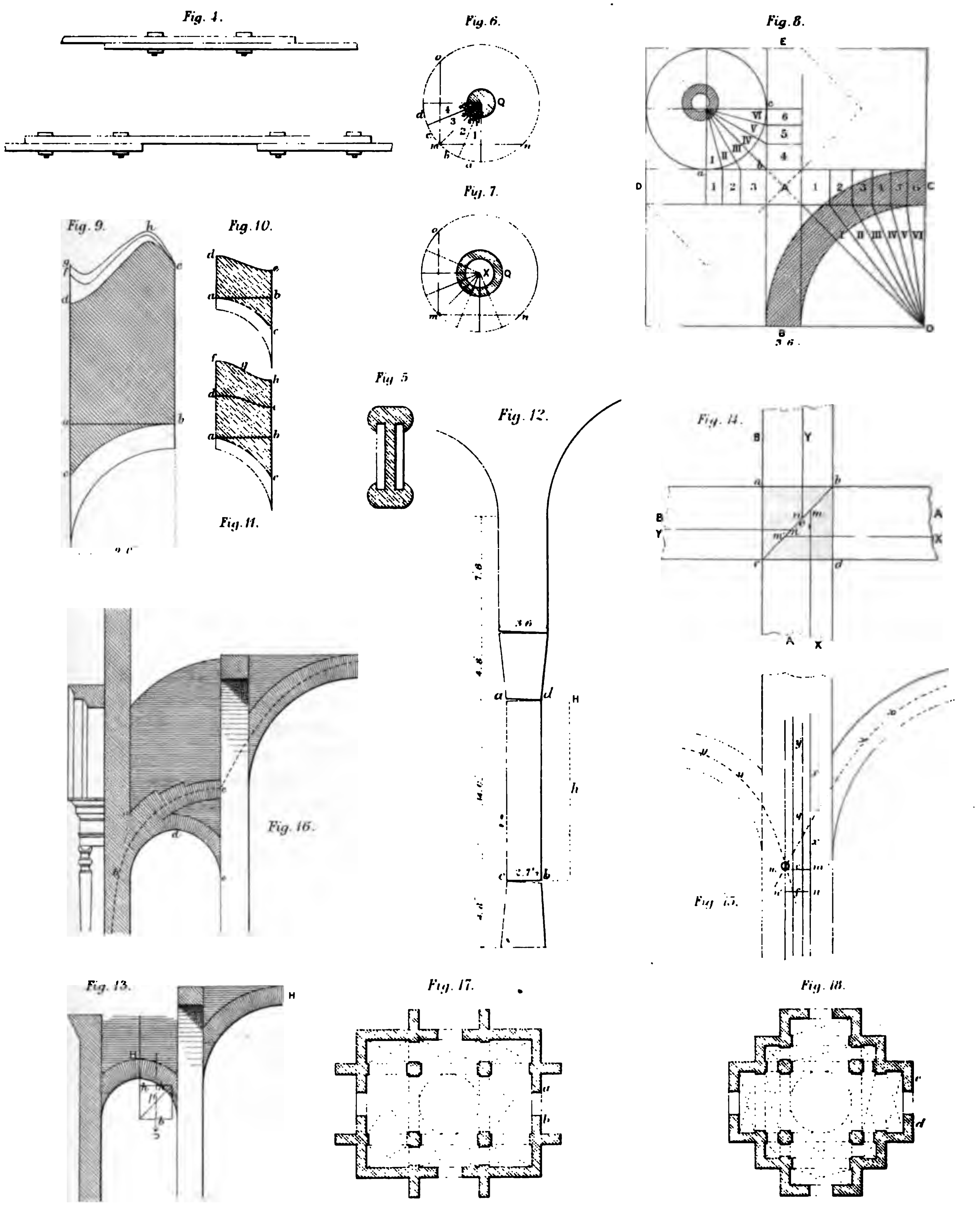
R. BERNHARD, ARCHITECT.

The Plans are half scale of the Section.

WYATT PAPWORTH, F.I.B.A. DIRT.

Lithog^d for the R.I.B.A. by Kell Bro^s London E.C.

THE KOLTOVSKOÏE CHURCH AT S. PETERSBURG.



R. BERNHARD ARCHITECT

WYATT PAPWORTH. F.I.B.A. DIR^T.

Lithog^d for the R.I.B.A. by [illegible] London, E.C.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 18th March, 1872, the following Paper was read, EDWARD I'ANSON, Vice-President, in the Chair:—

ON THE FALL OF THE DOME OF THE KOLTOVSKOÏE CHURCH AT S. PETERSBURG;

With an Account of the Edifice, and the Theory proposed for the safe Erection of such Structures; *being a Communication* from M. BERNHARD, Architect, of St. Petersburg, forwarded to and read by WYATT PAPWORTH, Fellow.

IN the newspapers of July 1864, appeared the following statement—"The freshly erected cupola, crowning the Church of the Transfiguration at St. Petersburg, came down on the 18th instant, with a terrific crash. The loss of life would have been comparatively limited, had not crowds of townspeople forced an entrance into the edifice, beyond all control from the police or military in immediate attendance. The concussion created by the falling dome in a short time brought down the whole structure, overwhelming several hundreds in the ruin."

Considering that probably this accident might afford some elucidation of old principles, or at least add some information to our then scanty knowledge on the subject of domical constructions, which has since been added to by the results of the investigations which Mr. Denison favoured us with last year, I availed myself of the friendship of a family in London, to urge their relation, residing in St. Petersburg, to obtain for me the particulars of this accident. It occurred to me that possibly some professional journal or newspaper published in that capital might afford a detailed statement of the accident; but I only displayed my ignorance of the "better way" they have of managing such things abroad, for nothing of the sort could be found. The relative, however, guessing that I was not searching for this information without sufficient reason, took up the enquiry, and forwarded a letter, which conveys so graphically the difficulties he met to fulfil my wishes, and the popular views of the cause of the calamity, that I cannot but add them in his own words, with a few remarks of my own as to the additional difficulties which arose to prevent this paper being laid before you earlier, a delay that has also been extended by urgent professional duties, necessitating frequent postponements of the evening on which it was to be submitted for your consideration; but a delay which has enabled me to add the result of the restoration of the edifice.

"*St. Petersburg, Dec.* $\frac{1}{13}$, 1864.

"You will think I have been very negligent in not answering your enquiry about the cause of the accident at the Koltovskoïe Church, but notwithstanding all my endeavours, I have found it impossible to obtain any information of any value; for all the vague answers I have received would be of no use to Mr. Papworth, who of course could be satisfied with nothing which was not accurate, and to a certain extent technical. I have seen a great many architects upon the subject. The case was very much exaggerated in the foreign papers, where I believe it was stated that several men were killed by the falling of the cupola, but in reality no lives were lost, for the accident happened during the men's dinner hour, and the only man who was inside the building escaped with a few bruises; still it excited much anxiety, as every body felt that if the building had held together a little longer, the cupola might have fallen upon the heads of a churchful of

people; in short no one was safe, and there was a general desire to know the cause of the misfortune. Somebody was evidently in the wrong, and a victim must be found. Whose fault was it? Had the architect made any error in his calculation, or had the builder been wrong in not following out the architect's plan, or in using inferior materials? It happened that the priests had, after accepting the designs, resolved to build the church themselves; this was from motives of economy, for they really had not money enough to complete the work. Here then was a capital fault, of which the architect's friends did not fail to avail themselves. The priests naturally endeavoured to show that the architect was wrong, and the public, who knew nothing at all about the matter, sided with one party or the other according to their personal sympathies. In such a state of things it was impossible to arrive at the truth.

"In the meantime the government appointed a commission of enquiry. I do not think a commission is a very rapid engine in any country, and I am quite sure that here it moves at the slowest possible pace. After many week's deliberation, the body came to the decision that there was something defective in the existing system of building cupolas, for accidents similar to the one at Koltovskoïe are of frequent occurrence, and in the course of the present year (1864) no less than *three* have occurred in different parts of the empire. Had this commission been named in England, a direct answer to the enquiry would probably have been given, and it would undoubtedly have been more satisfactory, for, having discovered the cause of one accident, a clue is found to explain all others of a similar nature. But a decision found upon the evidence in this particular case would probably have ruined the architect, and he (probably) had influence sufficient to induce the commission to adopt a resolution which would leave the question open.

"But the inquiry is to be continued by one member of the commission, a very competent architect, who is to present a report upon the present system of building cupolas, and to point out its defects. On procuring an introduction to this gentleman, M. Bernhard, I called upon him yesterday, and found him engaged on the work he had undertaken. He told me that the architect of the Koltovskoïe Church had made the mistake of following a system which was false and dangerous; where the mistake lay precisely it was difficult to say, he told me, until he had worked out his calculations, and this it would take him a month to do, as he is very much engaged, and cannot devote many hours at a time to this enquiry. But he promised to let me know the result as soon as he had finished his labours, and if it will be of any use to Mr. Papworth, I will endeavour to communicate it to you. The report will be published as soon as it is adopted; but as this may not be for two or three months to come, it will perhaps be too late to be of any use to Mr. Papworth. I will send it at all events, for though the letter-press is in Russian, the diagrams and figures will enable a professional man to extract some information from it.

"I am very sorry that I have not been able to procure any more satisfactory information than this. I would have written sooner, but I have always been led on by the hope that I should be able to find one professional man who was acquainted with the cause of the circumstances, and would tell the truth. The strangest thing is that they have all something to say about it. One says that the bricks were too soft; another, that the mortar was bad; some pretend that the foundation was not solid, while several have told me that the architect had warned the priests that they were not building solidly enough. M. Bernhard tells me that there is not a word of truth in all this, and I think Mr. Papworth will see that this gentleman is right in condemning the system, when I send him the plans.

"Koltovskoïe, the place where the church is situated, is opposite Petroffsky Island, where in former days I have often walked."

My friend in London, who had resided for many years in St. Petersburg, wrote when forwarding this communication to me, " It is very unsatisfactory, like everything in that country."

For the next four years I received no certain information as to this expected "report," until, through the same friendly channel, I obtained an extract from a letter, dated Plymouth, Sept. 19, 1868, stating that "a day or two before I left St. Petersburg (this was in the Spring of 1868) the enclosed manuscript was given to me by M. Bernhard, for the architect who wished to know the cause of the accident which happened to the church at Koltovskoïe. Besides showing the fault in the construction which led to the catastrophe, the manuscript developes quite a new theory in this branch of architecture, which the author thinks likely to be of very great value. Mr. Papworth is at liberty to make use of the manuscript, but on the express condition that he acknowledges the source from whence he procured it. M. Bernhard does not look to any profit from the discovery he thinks of so much importance, but he wishes at least to have the honour due to a man who has laboured hard, and not in vain, in an art of which he is so distinguished an ornament. I would beg you, therefore, to give it to no one but Mr. Papworth, at the same time making him acquainted with the condition. Should Mr. Papworth not require it, please seal it up and keep it for me until you have an opportunity of returning it."

Accepting the conditions, and assuring the architect, through my friend, that the subject would be brought before the Royal Institute of British Architects, I took the beautifully-written manuscript,* and neatly executed diagrams, to the Rev. Dr. Popoff, the clergyman to the Russian Embassy, who himself kindly gave me the pith of the composition; but he, along with other gentlemen to whom I showed it, gave up the translation as hopeless, on account of the technical expressions, which were not to be found in any Russian Dictionary. Under these unforeseen circumstances I sent it back to St. Petersburg, hoping to get it translated first into French under the author's inspection, and thence into English either at St. Petersburg or in London. In October of the year 1870, I was agreeably surprised at hearing that my Russian friend had arrived from St. Petersburg, bringing the manuscript with him, but, alas, not translated. Understanding the English and Russian languages, he read the composition through to me, endeavouring to master the meaning of the technical words, if he could not give the exact interpretation. I subsequently obtained a literal translation; spent many hours in going through it line by line with the translator; obtained a verification of it by another translator, and generally introduced the proper technical expressions; but some Russian words were still not understandable, necessitating further consultation with its author, who, perceiving the difficulties, kindly added to the diagrams already forwarded, a plan and sections of the building; these illustrations being in a language intelligible to every nation, needing no translation, we shall almost discern from them the author's thoughts, without reference to the manuscript. With all this care I still fear that in the following account may be found a few points not very clearly rendered.

" In 1861 was commenced the erection at Koltovskoïe, near St. Petersburg, of a stone church with five domes, dedicated to the Transfiguration of Our Saviour, the designs for which were approved by H. M. the Emperor on the 20th April, 1861. The brick-work was successfully finished in 1863, and the principal dome stood through the winter, the centering having been removed. In the spring of 1864 the interior stucco-work was commenced, and on its completion the scaffolding round the pillars was taken away in the higher part of the church. On the 18th June following, at ten o'clock, the principal dome fell down; three pillars also fell, while the fourth pillar was

* Now placed in the Library of the Institute, together with the original drawings.

forced from the perpendicular to a degree scarcely perceptible. The fallen pillars had the position indicated in Fig. 2 by the letters, A B, C D, E F. Consequently, as may be easily understood, the cross vaults between the principal supporting arches and the exterior walls, fell in. Of the corner vaults, however, only one half fell down, while the small cupolas built on the remaining parts of those corner vaults stood, though slightly inclined towards the interior of the church. No damage was observed to the exterior walls. The interior damage consisted of the vaulting of the floor being broken, and of cracks in the brick piers in the crypt of the church, serving as foundations to the pillars. The arches thrown across from one pier to the other in the crypt were also broken and fell down; but the arches thrown across from the piers to the exterior walls had no sign of cracks, except that on their flat surfaces the bricks were found in some places to be chipped. The pillars suffered two kinds of damage; first, the damage incurred during their fall to the edges of the beds of the bases, the capitals, and the shaft; and secondly, the damage which resulted as the consequence of their fall, principally to the corners of the capitals.

"Across the building were arranged iron ties, as shewn by the dotted lines 1, 2, 3, 4, (Fig. 2); they were secured to the axes of the pillars, and had their ends fastened in the exterior walls. Out of the holes L, M, N, O, the anchors or keys (*shtere*) were drawn; the ties G H and I K had two paws (*lape*) torn. These ties were arranged to pass through the head (*chaliga*, highest point of the vault) of the principal and supporting arches. Their dimensions (Fig. 4) are $3\frac{5}{8}$ inches, and resembled the ties generally employed for private buildings. Besides these ties, over the principal arches and under the base of the drum of the dome, was placed a double iron vertical ring (Fig. 5), the hoops of which were secured to one another by means of iron collars.

"*Execution of the works; quality of the materials employed, and detailed description of the parts.* The walls showed that the brick-work was executed in a satisfactory manner. Red bricks were employed for them, the mortar being made of Tosna lime mixed with sea sand. The parts that have broken down were to a great extent built of round empty bricks (literally, pots), (*gontchari*), besides the ordinary red bricks, many of which were found broken by the fall. The mortar of the broken down work appeared rather of a poor composition, which must be considered as a consequence of the violence of the fall of the dome and of the vaults from a considerable height, and also, probably, because heavy rains had set in for some time after the event. The pillars were formed of polished red Finland (Portlack) granite, the shafts being 18 vershocks in diameter and 6 arsheens in height (in English measure equal to 2 feet $7\frac{1}{2}$ inches diameter and 14 feet in height). The bases and the capitals were each 2 arsheens (*i.e.* 4 feet 8 inches) high, formed of the same granite, and secured to the shafts by means of dowels (*sterjene*) of round iron $1\frac{1}{4}$ inches diameter, and having a length of 9 or 10 vershocks ($15\frac{3}{4}$ English inches or $17\frac{1}{2}$ inches) as might be judged from the part seen; over the capitals the brick-work was carried up straight $3\frac{1}{2}$ feet square and $7\frac{1}{2}$ feet in height to the springing of the arches. The principal arches, as well as the side supporting arches, had the same breadth as the brick part of the pillars, and their thickness was $2\frac{1}{2}$ bricks. The side vaults, those to the cupolas in the angles, and the cross vaults in the space between the principal supporting arches and the exterior walls, were built $1\frac{1}{2}$ bricks thick. Over each corner vault was made a platform of brick (*rasboutka*), on which was based the cupola built of ordinary red bricks with some pot bricks in the middle. The drum of the principal dome was also built partly of ordinary, and partly of the pot bricks; the dome itself, 18 feet in diameter, was of kiln bricks (*gorchatchne*) with small brick arches introduced, which were one brick each way. The pendentives (*paroussa*) of the principal dome were built like the dome; over each pillar was made a brick support; as high as the roof of the church. The cupolas were covered with spherical

roofs, consisting of wooden trusses, covered with sheet iron on boarding half an inch thick. The church was not quite a square, being 49 feet by 51 feet 4 inches (English) in the inside; one side was thus longer than the other by 1 arsheen (2 feet 4 inches).

"To determine positively the cause of the accident, the stability of the church had to be tested on statical principles. The problem, at the first glance, appeared very complicated, but after a more attentive examination it was found it could be brought to a simple question of two loaded arches carried on one support that was to be kept in equilibrium by the reaction of the two equally loaded arches carried on the same support. It was more difficult to determine what law or rule regulates the transmission of the weights on the supporting arches; because examining, for instance, the principal dome, it is necessary to observe that its internal form is cylindrical with twelve faces on the exterior, whereas the supporting arches on the plan are square. Allowing this foundation, having four corners, to bear a weight of the figure of an empty cylinder, parts of the cupola are thrown into the angle spaces between the arches, those parts presenting the aspect of spheric triangles, called pendentives; so that the arches not only bear a portion of the direct weight of the cupola, but the rest of its weight is borne by them through the pendentives.

"The distribution of the weight on the arches presents no difficulty; for imagining to oneself how the pendentives transmit the weight and where it passes on to the arches, the whole dome (Fig. 6) might be examined; and supposing that the dome is loaded at its crown (*chaliga*) by a certain weight of a regular form, and also symetrically disposed, and supposing this weight to be represented by Q, then if the dome be divided into the small elements 1, 2, 3, 4, &c., the weight Q will be divided into the elements q_1, q_2, q_3, &c. It will be readily understood that on the foundation a of the element 1 passes the weight of the element 1 and part of the weight Q, namely q_1; on the foundation b passes the weight of the element 2 and the part of the weight Q, as q_2, &c. If $a = b = c = d$ then $q_1 = q_2 = q_3$, &c.; and if, likewise, the foundation of the cupola had been arranged on n elements, then a, b, c, &c. would have passed on each $\frac{Q}{n} =$ part of the additional weight. This rule of the transmission of weights, consisting of the weight of the elements of the dome and of the additional weight, does not change if it be imagined that the parts of the dome are cut off and replaced at the same time by the walls or by the arches $m\,n$ and $m\,o$, so that the equilibrium of the dome be not disturbed.

"This rule may still be applied if it be imagined that the upper part of the dome X (Fig. 7) is taken away, and that instead of a continuous weight there is disposed a supplementary annular weight Q; and from that it may be concluded that this rule also extends itself to the case when the part taken away of the dome X is made larger and together equals Q; and further, when the circle X touches the line $m\,n$ and $m\,o$, and when the ring Q partly goes on the walls or arches $m\,n$ and $m\,o$. But it was the last case that proved the property of the pendentive *to transmit the weight on the arches in the direction of the meridional planes;* and hence there was no difficulty in obtaining a clear idea of the distribution of the weights among each of the loaded arches. Examining, for instance, the quarter of the plan of the church (Fig. 8), where A is the pillar; A B and A C are the principal supporting arches; A D and A E the side supporting arches; then dividing the principal pendentive A B O and the corner vault $a\,b\,c$, by means of meridional planes, into many elementary parts as I, II, III, &c., and tracing perpendicular lines from the points of the meeting of the planes with the supports, the arches become divided into the parts 1, 2, 3, &c., having in the horizontal projection the appearance of rectangles; then it is evident with regard to the principal arches that a part of the weight of the drum, of the dome vault, and of the roof, indicated in Fig. 8 by I, passes on the part of the principal arch A C,

marked by 1; further, that a part of the weight of the drum, of its dome vault, and of the roof, marked II, passes on the part of the principal arch indicated there by 2, and so on of the others.

"The distribution of the weight on the side arches is similar, and does not require, therefore, any explanation; it is only necessary to observe that the arch A E was longer by 8 vershoks (= 1 foot 2 inches English) than the arch A D. This peculiarity required that the disposition of the weight should be examined separately for each of the side arches. Another of the above-mentioned circumstances complicated the calculation, namely, that the small domes had remained in their places by reason of their eccentric disposition on the side vaulting thus sustaining them; therefore two investigations were required. 1. The stability of the church without the participation of the side domes in the destruction of the thrust (*raspor*) of the principal arches; and 2. The stability of the church with the co-operation of the side vaults in the destruction of the thrust of the principal arches. After a calculation of the cubic dimensions of all the parts I, II, III, &c., tables were made; after that, these cubic contents were required to be brought to the breadths of the corresponding supporting arches, from which resulted other dimensions I, II, III, equal to the first, only with other quantities. Their foundations corresponded to the rectangles 1, 2, 3.... and the heights afterwards determined, served for the ordinates of the figures of loading of the principal, as well as of the side, arches.

"With regard to the principal arch, the loading, *i. e.* its figure, had the appearance approximately represented in Fig. 9, where the portion lined over indicates the loading, thus *a b c* shows the support (*rasboutka*); *a b d e* shows the weight of one-eighth of the drum of the dome and of the roof; *d e f* shows the weight of the half pendentive; and *f g h e* shows the weight of the support round the dome.

"As to the side arches, the figures of loading were calculated as represented approximately in Fig. 10, where *a b c* is the weight of the support, and *a b d e* that of the side dome vault. Also, taking into consideration the weight of the small or side domes, the figure of loading presented the appearance approximately, as in Fig. 11, where *a b c* indicates the support; *a b d e* the weight of the dome vault; and *d e f g h* the weight of the dome.

"*The planes of fracture and the greatest horizontal thrusts.* The planes of fracture were determined by means of the tables prepared by the French engineer Petit (and given in Claudel's *Aide Mémoire*, Art. 'Roads and Bridges,' as taken from No. 12 *du Mémorial de l'Officier du Génie*), in 30° to the horizontal line passing through the centres of the arches:—

The largest horizontal thrust for the principal supporting arch will be determined by—

$$H = 458{,}9 \text{ cub. feet.}$$

For the largest of the side arches without the weight of the small cupola—

$$H^{b} = 71{,}37 \text{ cub. feet.}$$

For the smallest of the side arches, also without the participation of the small cupola—

$$H^{a} = 78{,}66 \text{ cub. feet;}$$

For the largest of the side arches with the participation of the small cupola in the destruction of the horizontal thrust of the principal arch—

$$H^{b}_{k} = 135{,}63 \text{ cub. feet;}$$

For the smallest of the side arches with the participation of the small cupola in the destruction of the horizontal thrust of the principal arch—

$$H^{a}_{k} = 133{,}52 \text{ cub. feet;}$$

For the weight of the pillar, reckoning from its granite part up to the top with the support (*rasboutka*) over it, of the quarters of two cross vaults, and of the parts of two principal and two

side arches with the support and the loading of three arches that were over the planes of the fracture, and did not enter for that reason into the expression of the momentum of the thrust (without the participation of the small cupolas)—if all this be expressed by P, then—

$$P = 536{,}81 \text{ cub. feet};$$

The same weight, with the addition of the part of the weight of the small cupola becomes P^1 and—

$$P^1 = 544{,}69 \text{ cub. feet};$$

The weight of the principal arch with the loading—

$$Q = 678{,}41 \text{ cub. feet};$$

The weight of the larger of the side arches with the loading—

$$q = 134{,}26 \text{ cub. feet};$$

The weight of the larger of the side arches with the loading, and with the addition of the weight of one-eighth part of the small cupola—

$$q_k = 227{,}38 \text{ cub. feet};$$

The weight of the smaller of the side arches with the loading—

$$q^1 = 144{,}46 \text{ cub. feet};$$

The weight of the same arch with the loading, and with the addition of one-eighth part of the small cupola—

$$q^1_k = 225{,}86 \text{ cub. feet.}$$

" After these calculations, there had to be obtained :—

" 1. The expression of all those forces and weights in lines;

" 2. The drawing out of the curve of pressure on the arches, by the formula employed by the Prussian engineer Hagen (*Ueber form und Stärke Gewolbter Bogen.* 8vo. Berlin, 1862).

" 3. The determination of the general centre of gravity of the mass composed of the pillar and its loading;

" 4. The graphic determination of the further course of the curve of pressure under two suppositions: that is to say, without the participation of the small cupolas in the destruction of the thrust of the principal arches, and with their participation in the destruction of this strain.

"The result was, that in the first case, the diagonal curve of pressure was projected from the mass of the pillar in the upper part of the capital; and in the second case, in the lower part of the capital. Not taking even into consideration that in consequence of this unequal pressure the lower courses of the brickwork of the pillar must have been broken, the church would still have stood, although from a slanting pressure the whole pillar was subjected to a twist that caused the uncovering of the joints between the base and the shaft, and between the shaft and the capital, as shown in Fig. 12. This uncovering occurred at the points a and b (supposing that the edge $a\ c$ faces the exterior angle of the church), a fact confirmed by the damages to the angles of the masonry. But, in consequence of that uncovering, all the weight P of the portions supported by the pillar fell instantly on to the interior edge of the shaft; and then the falling down must have occurred when the momentum of the horizontal thrust $H.h.\sqrt{2}$ comes to be larger than $P.r.2 +$ the momentum of the shaft with the capital; then

$$H.h.\sqrt{2} = 22400 \text{ ponds (3 pouds = about an English cwt.),}$$

$$\text{and } P.2.r + rp = 16626{,}72 \text{ pouds};$$

consequently the equipoise was impossible.

" These deductions, in numbers, relate to the case of the non-participation of the small cupolas in the destruction of the thrust.

"Calculating the participation of the small cupolas in the destruction of the horizontal thrust of the principal arches,

$$H.h.\sqrt{2} = 22400 \text{ pouds, and for}$$
$$2r.P \quad rp = 17907 \quad ,,$$

and this deduction shows that even with the participation of the small cupolas in the equipoising of the horizontal thrust, the catastrophe would not have been avoided, and that it occurred *from an insufficient balancing of the thrust of the principal arches.*

We now come to the "*Measures to be adopted in restoring the Dome of the church:—*

"The stability of the dome may be obtained—

"1. By iron ties of proper dimensions and workmanship, arranged in due places ;

"2. By the loading of the side arches ;

"3. By both means together ; and

"4. By the alteration of the system of the interior construction by building up the openings of the side arches and placing them lower down.

1. "*By means of the ties alone.* It is possible to arrange the ties alone, from wall to wall, intersecting the axes of the pillars immediately over the capital, and with others also from wall to wall in the arch itself, being 8 ties in all, with iron bolts between their points of intersection. The lower ties must destroy the thrust weighing 1135 pouds, and prevent the slightest movement of the pillar. Considering that a square inch of transverse section of iron will resist 250 pouds, this section must in the present case be 4,5 square inches—that is to say, that the iron to be employed for one tie must be 3 in. broad, $1\frac{1}{2}$ in. thick, or two ties each 3 in. broad and $\frac{3}{4}$ in. thick.

"But sufficient dimensions of the ties, if they pass through the capital, as above said, will still not guarantee the stability of the dome; because it is necessary to take care so to transpose the curve of pressure as that the vertical compound pressure coincides with the axis of the pillar, which may be attained by an iron bolt of the necessary dimensions.

"Having determined the dimensions of this bolt by means of the approximative formula:—

$$H = \frac{16\,m\,R}{z\;l} \qquad \text{where } \frac{m}{z} = \frac{x^2}{b}$$

$$H = 1135 \text{ pouds.}$$
$$R = 250 \quad ,,$$
$$l = 198 \text{ inches}$$

from which x, nearly $= 4$ inches.

"Although this dimension is still not quite sufficient, because x should have been determined by the formula—

$$H = \frac{8\,m\,R}{z\;l}$$

but nevertheless these dimensions clearly show that the lower the tie is disposed, the thicker must be the bolt. If the tie had passed higher, the bolt might have been thinner. The success of the ties depends on their proper arrangement, on their proper preparation, and on the good quality of the iron ; these conditions are rarely found together. If the first condition is observed, it remains still uncertain to what degree the two last are observed ; and the success of the whole depends more on the good workmanship of the smith in the preparation of the ties than on the efforts of the builder. It is necessary to observe furthermore ;—

"1. That the ties may be destroyed in a certain time by injury done to them by lime, if any negligence has taken place in not preserving them against rusting.

" 2. That the ties change in length from alterations of temperature.

" 3. That the ties may become red hot in case of fire, that they then lengthen considerably, and are useless, causing the thrust to reappear.

" 4. That the ties do not add to the beauty of the interior of the building; and, lastly,

" It is necessary to observe, concerning the present case, that if a thin bolt had been employed, the presupposed tie would not hinder the dome from falling down, because all the brick part of the pillar might have fallen in the angles, and its granite part should have remained in place.

" 2. *By means of the loading of the side arches* :—If it be intended to establish the stability of the principal dome by means of loading, it is necessary to place on the side arches so much material that its thrust be equal to that of the principal arch. Let P (fig. 13) indicate the weight of the loading, and p the weight of the side arch; h, the vertical distance from the point of connexion of the thrust H to the point of rotation in the plane of the fracture; and let b represent the horizontal distance of the general weight $P + p$ from the same point, then P will be determined by the following equation:

$$H.h = (P + p)\, b, \qquad \text{whence } P = \frac{H.h}{b} - p;$$

" The height of the small wall placed on the side arch depends on its situation between the arch and the roof of the Church, while its thickness more or less depends equally on the breadth of the arch; and the length of this small wall depends on the half of the length of the side arch, so that the thickness of the small wall remains to be determined. If from the equation the thickness of the wall be greater than the breadth of the arch sustaining it, it will be necessary to arrange the side vaults so that they may by their gravity make up for the want of weight of that loading wall; or if that be insufficient the angle cupolas must be built heavier.

" But the following points require attention :—

" 1. That the point of connexion of the side arch with the pillar must be chosen so as to make the general weight brought on the pillar pass through its axis.

" 2. That this point depends not only on the point of intersection of the curves of the pressure on the pillar, but that it depends also on the horizontal position of those curves, because the principal arch, as well as the side arch, are subjected to a side loading, and in consequence of that, the curve pressures approach in the principal arches more to the centre of the Church, and in the side arches they may approach nearer to one or other of their exterior surfaces. This depends certainly on the question if the vault has, in the space between the principal arch and the exterior wall, more influence for the destruction of the principal thrust, or if on that a greater influence is exercised by the angle vault and its loading. In every case those horizontal turnings aside of the curve of pressure must be determined.

" Figure 14 represents the plan of a pillar, $a\,b\,c\,d$; A A represent the principal arches; and B B the side arches. Supposing that the curve pressures will be intersected at the point O, it is necessary to examine on the plan if this point correspond to the axis of the pillar or not. Let the horizontal projections of the curve pressures be X and X, Y and Y, and let their vertical projections be x and y (Fig. 15). Continuing on the plan the curve pressures up to m and n on the diagonal $c\ b$, then on the curves $y\ y$ and $x\ x$ in the vertical projections there will be found

two points m' and n'. Then in Fig. 15 draw through m' and n' horizontal lines, as m' m''', n' and n'', until they meet with the vertical projections X′ and Y′, and unite the centres of those horizontal lines by the line $e\,f$. Should the points e and f coincide, then the side arch is correct; and if they do not coincide, the arch $y\,y$ must be raised a little, or lowered, until the points e and f do coincide, and only then has the small arch its proper position.

"3. That these means have the inconveniency :—(*a*) That it requires a quantity of material double that which is actually required for the loading, because it is evident that only half of it is employed to resist the thrust of the principal arches, and that the other half forms a useless weight. (*b*) That the point of connection of the side arches relatively to the exterior walls will always be placed tolerably high, by which the moment of the rotation of the exterior walls becomes greater, and the construction of strong counteracting forces becomes an absolute necessity. (*c*) That this means of equipoising the side thrust of the principal arches by the loading of the side arches of a symmetric form, can be employed for new buildings when the masses of the exterior walls may be with facility arranged in conformity with the conditions of the most advantageous resistance to the pressure on them of the thrust. (*d*) That therefore this system can rarely be applied in the restoration of old churches not having walls sufficiently thick for it, and possessing besides no counteracting forces. For this reason alone the system described proved to be not easily applicable to the Church of Koltovskoïe. Moreover the following circumstances had to be considered :

"1. The transverse section of the brick part of the pillar is equal to $42^2 = 1764$ square inches. This area receives the pressure of 6082,35 pouds,* therefore each square inch is loaded already by 3,44 pouds.† The lower courses of the brick part of the pillar are on this account already unable to receive any considerable additional weight. From this it results that it is impossible to rebuild the dome by means of an augmentation of the loading of the side arches; this alone is sufficient; the pillars would have to be made thicker, and they require on the contrary to be lightened.

"2. That the height of the granite columns must be lessened, because the broken edges must be cut off, shortening the columns by 2 feet.

"3. That of the exterior walls, the one at the altar end and the one opposite to it, were found sufficiently solid for receiving a considerable side thrust; the other exterior walls are considerably weaker, so that even in the case of lowering the point of connection of the horizontal thrust, it becomes necessary to consider how to strengthen their stability.

"All these reasons and circumstances led to the recommendation that the dome of the Church of Koltovskoïe should be rebuilt on the following system :—

"1. The side arches not to be rebuilt in their former position.

"2. In lieu of them should be constructed a counterfort or flying buttress, *a b c*, Fig. 16, connecting it with the pillar opposite the place where the line of pressure intersects the axis of the pillar; this counterfort is to be loaded until its horizontal thrust be equal to the horizontal thrust of the principal arch. The form of the loading shown on Fig. 16, was selected to approach as much as possible the

* About 101 tons 7½ cwt.

† About 1·15 cwt.

general centre of gravity to the key-stone of the arch; the height of this loading was determined by the open space between the arch and the roof. The calculated thickness of this loading, the breadth and height being given, was determined at 35,16 inches or at 3½ bricks. There was no necessity to construct the vaults over the area of the Church, thus increasing the thrust, and therefore the proposal to rebuild indicates the formation of cross vaults, the weight of which can be transmitted on to the pillars and on to the exterior walls. In order, also, to preserve the characteristic form of all the vaults and arches, it was proposed to build the decorative arch *d e*.

" By this arrangement was attained:—

" 1. The greatest possible lowering of the thrust relatively to the exterior walls.

" 2. All the material employed in loading the counterfort is employed really in destroying the thrust of the principal arches.

" 3. The pillars do not receive a considerable supplementary weight; and

" 4. The supplementary curve of pressure has passed through the middle of the foundation of the exterior wall.

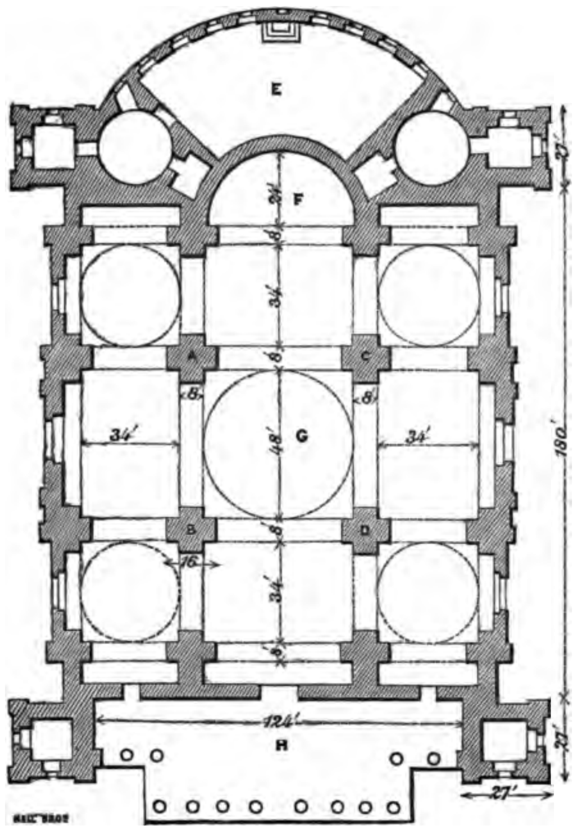
" In conclusion, it is necessary to observe that the system of rebuilding the church by a temporary adaptation of the ties and of the loading, has not been submitted to separate examination, because its proper application is difficult. It will probably be impossible to dispose the masses thus and to strain the ties so successfully that their counter action may begin at the same moment, and therefore in the contrary case the success becomes doubtful.

" From all the considerations for placing in equipoise the thrust of the principal supports, the most advantageous is the employment of masses, some of which are used as loadings, and others serving to strengthen the exterior walls as counter forces opposite the line of the supporting arches, as shown in Fig. 17. But every intelligent builder would have moved the walls *a b* to the places indicated by *c d* (Fig. 18), and then the form of the church would have taken the arrangement represented by the plan Fig. 18; and of such a form as that, it may be said that the plan of an orthodox church, presenting the shape of a cross, *is a form not only symbolically true, but also constructively indispensable.*

" (Signed) BERNHARD, *Architect*."

I have yet to state, that the Church has been restored upon the principle on which M. Bernhard's theory is based; and in the words with which my friend concludes his last letter, dated March 22 (April 3), 1871, " you may imagine the proud feeling of satisfaction with which he stood under the dome when the scaffolding was removed. Since 28th October, 1870, the building has stood without any signs of failure appearing, and it has completely satisfied him in every respect. I am sorry you cannot see the building itself. M. Bernhard is preparing a voluminous report on the reconstruction of the church, from which he promises to send you extracts, but I think it will be some time before this is ready."

In the 'Transactions,' vol. ii. p. 93, is printed a valuable essay by Herr Hallmann, *On the Plan, Arrangement and Decoration of a Greco-Russian Church;* and in the 'Sessional Papers,' 20 January, 1868, will be found that very valuable Paper *On Russian Architecture*, written for, and read to, us by our esteemed Vice-President, Edward I'Anson.



In the "Sessional Papers" of 8th June, 1868, a notice is given of "*the Fall of the cupola of the Leopoldstadt Basilica at Pesth,*" forwarded by Professor Lange. The plan of it was given (it is again introduced for ready comparison with the building under consideration), and the description states that one of the piers, 16 feet across, showed signs of fracture at 12 feet above the floor, when it was loaded only with its share of the drum of the cupola. The failure of this church, one somewhat similar in plan to that at St. Petersburg, was attributed to defective workmanship and to the mixed materials of soft limestone and brick courses with which the piers were built, affording unequal powers of resistance.

FALL OF THE IRON DOME OF THE ANTHÆUM, AT BRIGHTON.

THE iron dome of the Anthæum or Oriental Garden, situated at the western extremity of Brighton, fell in at a quarter to seven o'clock on the evening of Friday, 30th August, 1833. The dome was composed of wrought and cast-iron ribs resting on a brick foundation, and weighed between 400 and 500 tons. The erection of such a vast dome in those days was considered an important event, and in iron certainly without a parallel. It exceeded in diameter that of St. Peter's, at Rome, by 36 feet; the width of the dome at bottom being 164 feet, and the height from the ground to the top of the ring exactly 64 feet; with the cupola it would have been 80 feet or more in height outside. The dome was not, like St. Peter's, placed on a height; but it rose at once out of the ground.

It was commenced in July, 1832, from a design by Mr. Henry Phillips, the well known botanist of the town, after having been submitted to some of the first engineers and architects of the day. Mr. Henry English, of the Griffin Foundry, Clerkenwell, contracted to erect the building under an engineer and architect of his own appointing. On the 29th July, 1832, Mr. Henry Wilds, as architect, laid out the ground, and the brick foundations into which the iron principals were built, were proceeded with. The scaffolding was erected in circles five in number, each ring exceeding the other in height. Principals after principals were bolted into position under the inspection of Mr. Peter Hollis, the

engineer; but a misunderstanding arising between the architect and the engineer, the former was dismissed. The engineer then ceased to give his personal attendance at the works; delays ensued, which were at last accounted for by the embarrassment of the contractor's affairs. Still the works proceeded; the iron work of the dome was all but completed; and several weeks before the accident the scaffolding had been struck. Some doubts arising as to its security, a second engineer was called in, who proposed some additional iron purlins. The scaffolding was again raised, and struck, being entirely removed by seven o'clock on Thursday evening. The writer of the article in the *Brighton Guardian* newspaper (of Sept. 4th, 1833, from which these notes are obtained) had remarked the heavy appearance of the top and a peculiar twist of some of the ribs which had acquired a considerable bend. Mr. Phillips was occupied during Friday under the very centre of the dome, marking out the formation of an aquarium. A little before seven o'clock, a gardener was alarmed by a loud cracking noise, when in a few seconds the whole top part of the dome fell in, and during the night many of the principals which had remained standing came down with a crash.

Of the cause of the dome falling, there were various opinions; but the most general one was that the dome was much too flat on the top. Mr. Phillips' design showed a half-circle, with a support in the shape of a pagoda in the centre. Mr. Hollis dispensed with this and made the dome much flatter. It was also intended that the large ring upon which the ribs rested at the top should have been 27 feet in diameter; but that size being found inconveniently large to cast, it was reduced to a diameter of 7 feet, and another row of principals added; so that the flatness of the dome was by that means increased and its security diminished, for the ribs lost their strength before arriving at the centre, and instead of pressing towards the ring, their own weight gave them an inclination to fall, and the ring intended for their support really acted as a lever to pull them down. The ring and two rows of the principals fell in one mass to the ground; indeed it appears that the top fell right through the dome, and the iron gave way as nearly as possible at the point where the flatness commenced. It is also thought that the ribs acquired a twist, and so the whole building screwed round (as it were) together, and got out of its proper position. The brick walls and foundations into which the bolting of the ribs were built stood as firmly as ever. It was hoped at the time that the Anthæum might have been reconstructed, but this has not been done.

If any member possesses a record of this building, it would be desirable that a copy of it should be deposited at the Institute.

Mr. EDWARD TARN, M.A. Associate.—I can corroborate what Mr. Papworth has said. No doubt, looking at the three arches in the section, the two side ones could not resist the thrust of the middle one. The thrust of an arch being as the square of the span, and the side arches being 11 feet, and the centre one 18 feet, the thrust of the latter was more than double that of each of the former, and therefore more than half the thrust of the larger arch would be unresisted. It is a common error, as I think, all over the world, putting small arches to counterbalance the thrust of large ones without due consideration. With regard to the iron ties, I do not see of what use they are. They could not resist the thrust of the dome; the best way to do so, would be to put a *chain* bond round a little above the springing of the dome: but iron ties, which vary in length according to the temperature, unless they are built in the walls, do more harm than good. The cause of the fall is, no doubt, simply that the smaller arches were built with the idea of resisting the thrust of the large one. I have often seen modern churches with a large chancel arch and small arches formed at the sides, the consequences being that the piers are thrust out of perpendicular. The thrust increases, as we know, directly as the square of the span, so if the span of the arch be doubled, the thrust is quadrupled.

Mr. JOHN P. SEDDON, Fellow.—I beg to propose a vote of thanks to Mr. Papworth for this interesting paper. As Mr. Tarn has very properly said, in many modern churches we have a similar problem before us; but it is different to a slight extent, because the thrust of a pointed arch is not so great as the thrust of a circular arch. I have recently completed such an arrangement at Fishponds, near Bristol, with the side arches much smaller than the central one. The precaution I took was to put in beams at the springing of the smaller arches, which form the cornices, it parcloses and materially assists as struts. These act as abutments against the thrust of the larger arch, until the whole work, the spandrils of which are executed in Portland cement, is set, when the wing walls, though with holes in them, will suffice in themselves for that purpose.

Mr. T. MORRIS, Associate.—I should be glad if Mr. Papworth will be good enough to point out a little more explicitly where the failure occurred. The arches appear to be stilted, and I have not been able to follow where the fracture took place, whether in the stilting, or in what part. I should also be glad to hear what evidence there is to shew it was from any circumstance of equilibrium at all, and whether it was not clearly from the imperfect construction of the piers, which, having taken the form of a sort of rubble work, cracked under the pressure of the superstructure, and came down. I do not see that it is a question of equilibrium at all, and as far as the dome is concerned, that idea must be given up. Looking at the title in the Notice Paper, I came here this evening in the hope of hearing some highly scientific discourse, on a subject to which no one is able to do more justice than Mr. Papworth himself; but this building, I fancy, is merely the result of a piece of bad construction, which would be very likely to arise from the clergy taking the work into their own hands.

Mr. PAPWORTH explained on the section where the pressure took place; as is also shown in the diagram (Fig. 12).

Professor KERR, Fellow.—The probability is that the arches 1 and 3 (Fig. 2) were not sufficiently resisted by the two small arches. The combined influence of these pressures would send the thrust from B towards A. There was a slight discrepancy in the balance, and that caused the fall.

Mr. PHÈNÉ SPIERS, Associate.—Nearly all the Greek Churches are founded upon the great type of St. Sophia at Constantinople. At the same time, in looking at the section of this church which Mr. Papworth has prepared, we are able to see a material difference in its construction from those of the earlier Byzantine period, and those constructed at later periods in Constantinople up to the 16th century. All the churches in this latter town have very much larger central domes than this one, so large that all the services are performed under the central dome, and what we may here call the side aisles are only used for passages. The construction of these large domes was naturally attended with considerable difficulties; it would seem therefore that the architects of these later churches have found it more economical to build much smaller central domes, and give a greater width to the side aisles. At the same time they wanted to keep up, to a certain extent, the grandeur of the church and therefore they found it necessary to raise the arches of the side aisles to the same level as those supporting the central dome. In this departure from the original type I think they made a mistake, and the error is pointed out in the means that have been taken to counteract the mischief in this case, it being understood that in the earlier Byzantine Churches the smaller semi-domes or abutting arches over the aisles were placed at a much lower level, and hence served the same purpose as that now proposed by M. Bernhard.

Mr. PAPWORTH.—I had hoped, when I wrote first for information, to have received a paper relative to the failure of a dome, but it was only on taking up the manuscript last week I found the contents related to the fall of a church rather than to the fall of a dome. I had no other facts before me at first than what were furnished by the newspaper paragraph I have read to you at the beginning of the paper.

Mr. C. BARRY, Fellow.—Can Mr. Papworth inform us what the materials were of which the supporting piers were formed? [Mr. Papworth: granite.] The stilting part I apprehend was brickwork, and beneath that the granite? [Mr. Papworth: Yes.] I should like also to ask what the superincumbent weight per foot square upon the pier, both on the granite and on the brickwork above the stilted part, really was? I feel inclined to agree that the cause of the accident may as reasonably be sought from the possible insufficiency of the materials to resist the dead weight on the piers and foundations, as to any question of disturbance in the equilibrium of the arch as such. I should like to know what was the superincumbent weight per foot super. on the piers?

Mr. COCKERELL, Fellow.—If the failure arose from insufficiency of materials, would there not have been ample warning of it? If it had anything to do with the crushing of the piers, the fact would have been apparent by fissures in the piers.

Professor KERR.—The crushing of a pier and bending under the influence of disturbed equilibrium, would be, as regards the phenomena, very closely together. The result would appear in the same form very likely from a combination of causes: but the disturbance of equilibrium may have been expedited by insufficiency of material. If the material had been superior to what it was, the fall might have been protracted to a later period. I beg to second the vote of thanks to the gentleman who has supplied the interesting communication we have heard this evening, and to Mr. Papworth for the great trouble he has taken in bringing it before us.

Mr. PAPWORTH.—I do not think M. Bernhard states the total weight per foot super. He says that after the church fell the bricks were found not to be much broken, and the mortar was good; so that I doubt whether there was any crushing going on. A pier, 16 ft. square, in the church at Pesth, gave way from crushing, from the beds being of unequal construction. (The weight is given on p. 80).

Mr. AITCHISON, Fellow.—In a case where crushing and thrust exist together, the weight put on may not of itself be sufficient to crush, but, as there is a thrust as well, only a portion of the material is engaged in resisting the crushing force, whilst another portion is engaged in resisting the thrusting force, and thus the weight on the brick pier, above the cap of the granite pier, might not have been absolutely sufficient to crush it, but a portion of its resisting powers were occupied in resisting an improper thrust. It is possible only a certain portion was injured in actually resisting the thrust. Those who have visited Gothic churches, where the piers are very slight, will have seen how the thrust of the arches has bent them out of shape. At the Temple Church the columns are very much out of upright from the difference in the force of the thrust of the main vaults, and of the aisle vaults. I do not know of what particular use these iron ties were, being so much above or below the lines of thrust; for unless they are but very little above the line of thrust, and are carried down by long anchors, or keys, they are absolutely useless. We know, in many cases, warehouses have fallen down with brick arches supported by iron girders, where the ties have been put above the arches. We are very much indebted to Mr. Papworth for this paper, and, after all the trouble he has been at in getting so much information, we can scarcely ask him to do more; still, knowing as we do, how extremely kind he is in these matters, we may perhaps venture to ask him to apply to M. Bernhard to give us a little more exact information on different points of importance. It would be interesting to know whether the dome was the first portion that gave way, or whether the dome fell from the piers slipping out. We should also be glad to know the exact weight the brick piers above the granite caps carried, and also the crushing weight of one of the bricks, and of a foot cube of the brickwork (for the weight which a brick will carry gives only an approximate idea of what brickwork itself will carry); also what sort of granite was used, what it carried, and what is its crushing weight per inch; what the material was between the joints to equalise the pressure; and if we can get it, what was the actual

weight borne by the piers under the granite shafts; and what was the thrust from each arch or vault concentrating on the brick pier above the granite cap of the pier or column.

The CHAIRMAN said—Before putting the motion of thanks to M. Bernhard and Mr. Papworth, for the joint labours which have resulted in this communication, I would say a few words on the subject. In my own mind, the explanation Mr. Tarn has given, and an inspection of the diagrams are quite sufficient, and it needs no other theory to account for the calamity which befell this edifice. The paper is one of some interest to me, not because I am able to follow the mathematical calculations which are appended to it, but because it reminds me of the buildings of this character I have myself seen in Russia. This church is very much a type of all Russian churches. They are all square buildings, but many of them are added to by a nave and apsis, which is shut off from the rest of the church, and is only used by the priests; but the churches themselves, as Mr. Spiers says, are square buildings. Another characteristic of these churches is the introduction of four central columns or piers, symbolically representing the Four Apostles. These columns are more or less solid, some massive square piers, and some only pillars; all the churches are crowned with a central dome, generally raised on walls forming a drum or hollow cylinder under the dome, and generally with four surrounding smaller domes, which spring from the four corner chapels formed by the division of the square space by the four central columns. It is the corner, in the Russian churches, which is the holiest part of the structure; and in the principal churches of Moscow the holiest sites are always considered to be at the corners, and even in Russian houses the corner is the most sacred part. The external form of the church dome is entirely masked by a superficial wooden construction. In the same way the dome of the Byzantine Church of St. Mark's at Venice, and St. Frond at Périgueux are masked by a wooden roofing. These wooden external domes constantly assume the form of a bulb, or onion shape; and one of the greatest domes of Moscow, the St. Saviour's Church, outside the walls of the Kremlin, is a very pleasing specimen of the onion-shaped dome, which, when well treated, is a really graceful shape. These domes are covered with iron. Moscow stands in the centre of the widest continent in Europe, far removed from the atmospheric actions which obtain in ocean-bounded countries. Hence no city in Europe has so dry an atmosphere as Moscow; consequently iron plate, which would soon become rusted with us, remain unrusted there. They cover them with green paint, and so they last for a great length of time. The Russian priests have the reputation of being generally an uneducated and ill-informed class of men; therefore for them to be their own architects must be a blunder. But I was surprised to hear the statement in the paper that in the case of this church there was a want of funds; because in all the churches, the screen or Iconostasis, which shuts off the portion of the church in which the priests prepare the sacred elements, is for the most part decorated with jewels and gold, of great value, and precious stones of the most costly description, in profusion. In apparently humble churches which I have seen, the wealth bestowed in this manner is very great indeed—and that too in a country where there is no metallic currency, all the money circulation being in paper, and where all the material riches seem to be nailed to the walls of the churches.

The vote of thanks was unanimously passed, after which the meeting adjourned.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 22nd April, 1872 (THOMAS H. WYATT, President, in the Chair), the following Paper was read—

OUR PRESENT KNOWLEDGE OF BUILDING MATERIALS AND HOW TO IMPROVE IT.

By Captain SEDDON, R.E.

A CONVERSATION on the subject I have the honour to bring before you this evening, and a promise to write the paper I am now about to read, must be accepted as a sufficient reason for my appearance here, in the, to me, unwonted capacity of a lecturer before a learned body of professional men. It may not be out of place to preface my subject by pointing out that the most successful architect, as well as the most successful engineer, I hold to be he who produces the best results out of the least expenditure on materials and labour, or rather workmanship, for I allude to the labour of the hands as distinguished from the labour of the head; for therein lies the great difference between scientific and unscientific construction, between true art and worthless imitation, spiritless copyism. The more we advance the greater becomes the expenditure on headwork, and the less on mere handwork and materials; the great brain problem of the day is how most successfully to economise both matter and force.

The principal charm to my mind in the work of the Mediæval builders, when comparing it with the architecture of Greece and Rome, is the evidence it always bears about it of head work; the workmen stand there unbosomed before you, you seem to read their very thoughts, and to appropriate to yourself the pleasure with which they laboured to carry out their own ideas. You cannot look at one of the cathedrals of the Middle Ages without acknowledging to yourself that those builders strove to make the best use of the materials they found to hand. On the other hand, turn to a Grecian temple, and stately and beautiful as it undoubtedly is, perfect in proportion and in the refinement of its adornments, there is no soul, no life in it at all; there is plenty of labour of hands, mathematical precision of thought—thought of the architect but not of the workman—and materials regardless of cost; but in vigour of thought, in an appreciation of the true value of stone as a building material, and in constructive skill, the Grecian builders can bear no comparison with those of the Middle Ages. Give him but a few bones for his guidance, and an architectural Owen could almost reproduce the original, so rigid and exact were the laws which governed its growth, and fettered the fancies of its builders.

Engineers have to a greater extent than architects been compelled to study the nature and strength of materials, and especially of iron, which (used as it is by the former for every kind of work) has to be dealt with so as to economize both weight and material to the utmost, and to make the best possible use of its enormous powers of resistance to strains of every description. In fact the extensive use of iron for constructive purposes may almost be said to have given birth to the profession of civil engineering as distinct from that of architecture, the result of which has, I think, been a

tendency to too exclusive a cultivation of art on the one side, and of science on the other, to the manifest disadvantage of both professions.

Inasmuch as the architect aims at the beautiful in his constructions, as well as the useful, his profession is of a more elevated character than that of the engineer; for by assisting to cultivate the public taste he leads towards the source of all beauty and purity. Engineers confining themselves too closely to one idea—namely, the theoretical perfection of their work—have fully met the want that gave them birth, have shown how maximum results may be obtained from a minimum expenditure on labour and materials; but in mastering science they have too much neglected art, and even at times justified the absence of any aim at the beautiful, by affecting to rise above such ideas into the regions of the stupendous and the grand; but, unfortunately in minor undertakings, in little works which cannot aspire so high, we still find the same absence of any attempt to please the more cultivated feelings of our nature; or if the attempt is there, it is mostly too evident that a given sum has been expended upon purchasing a mask to hide not the loveliest of structural details below.

I know we have high ministerial authority for banishing art from our daily life, and confining it to structures erected solely to the glory of God, though even there, I suspect, in the official mind it would only be tolerated in deference to the misguided views of the populace, who will soon be told that they would derive more benefit from public worship were there no architectural distractions about them, nothing to make them mistake for religious feelings mere sentiment which arises from the surroundings of art.

That there always must be a radical difference between the two professions of architect and engineer is clear, according as the tastes and bent of different minds lead individuals to devote their energies, more or less exclusively, to certain kinds of work. I conceive however that members of both professions would be better for working more together, for a freer exchange of ideas; the country at large would derive more pleasure as well as benefit from works of engineers, whilst the employment of architects would be looked upon less in the false light of an expensive luxury beyond the reach of all but the favoured few, if they were regarded more as scientific constructors, who, combining a knowledge of, and true feeling for, art, were sure to produce a better built, better planned, more healthful, more beautiful, and less costly building than could be obtained without their aid. At any rate with regard to the last point, in aiming at economy, in striving to obtain the best results from the least expenditure on materials and hand labour, both architects and engineers stand on common ground; but, in order to succeed in this aim, it is necessary that we should be thoroughly acquainted with the capabilities of all the materials we may require to make use of, for resisting every kind of stress to which they could be subjected.

Now, the question which I mean to raise this evening is, whether we are yet sufficiently acquainted with the properties and strength of the different materials in common use for building purposes to enable us to employ them to the best advantage, or to allow of our calculating with accuracy the amount of material necessary, in every part of a structure, to meet the different stresses called into play?

It may be said by some, What more information do we want than that already within our reach? There are hand-books enough, in all conscience, with copious tables, giving the strength of all kinds of materials under every description of stress, and formulæ for calculating the requisite dimensions of beams, columns, &c., of different forms and under varied conditions: surely we are in possession of all the information any one could possibly require. Nevertheless, I think it must be admitted, on a little reflection, that the present state of our knowledge in these matters is, in face of the boasted enlightenment of the nineteenth century, by no means so satisfactory as at first sight might be imagined; or in any way sufficient to warrant our resting content without making any further researches.

Most of the data upon which calculations have hitherto been based, have been derived from experiments made on picked specimens, too small in size, and too free from such ordinary defects as are sure to occur in larger specimens, to give us very reliable grounds to go upon; the result being that we are forced to supplement our defective knowledge by using large factors of safety; or, in other words, by not straining the material used to anything like its estimated powers of resistance.

I know that it may be argued, on the other hand, that any slight defect would weaken a small section more than a larger one, and therefore that the great difference of strength attributed to the careful selecting of specimens might, in a great measure, be counterbalanced from the certainty of there being some slight defects, even in the most carefully selected specimens; but in this case we are only dealing with probabilities, and not with ascertained facts.

Again, the results obtained from different experiments made by Muschenbrock, Rondelet, Rennie, Barlow, Hodgkinson, Fairbairn and others, vary so considerably that little or no reliance can in many instances be placed upon them; nor are these discrepancies difficult to account for, when we consider that the experiments were made by many different hands, with different degrees of care, on a comparatively limited number of specimens, and that the means employed for carrying out the experiments differed in almost every instance, being often of such a kind as to be incapable of recording any accurate results. Let us glance at some of the discordant results obtained, in order to see how much value ought to be attached to them.

TIMBER.—Taking the subject of *Timber* first, I cannot perhaps do better than quote from a valuable little treatise lately published by Mr. B. Baker, C.E., "On the Strength of Beams, Columns, and Arches." At page 127 he says:—

"Unfortunately, most of the careful experiments of Tredgold, Barlow, and other early investigators, were made on small pieces of timber, straight-grained, and free from knots and other defects; a condition favourable, it is true, to the comparison of the results of mathematical investigation with those derived from direct experiment; but, on the other hand, leading to errors of much greater moment in actual practice, since (as every workman knows) a piece of timber uniformly sound throughout can never be reckoned upon." He then goes on to show the per-centage of loss of strength due to the inevitable defects in large scantlings, as follows:—A piece of English oak 2" and 1" square gave a result equivalent to a breaking weight of 8½ cwt. applied at the centre of a 1" square bar supported on bearings 12" apart, giving a calculated stress on the extreme fibres of the bar equal to 7·6 tons, or 17,024 lbs. per square inch, a surprisingly high, and, as far as practical cases are concerned, a palpably exaggerated result. Whereas, taking a larger scantling of oak, 11′ 9" long and 8½" square, the calculated stress on the extreme fibres, when rupture took place, was only five tons, or 11,200 lb. instead of 17,000 lbs. per square inch; and a larger beam still, 24′ 6" long, 12¼" deep, and 10¾" wide, gave a result equivalent to less than one-third of that given by the small selected piece. He then says:— "This reduced amount shows that the average strength of the timber in this large beam was less than one-third of that in the small selected piece; and we think no further illustration is required to show the necessity of neglecting the majority of experiments made on small scantlings of oak, when deducing rules for practical application. We find the same conclusions hold good with reference to Riga, Memel, pitch pine, and other soft woods," the standard bar 12" by 1" square, giving a maximum stress on the fibres of 3½ to 4½ tons per square inch, whilst experiments on a beam 15 ft. long and 12" square give a maximum stress of only 2¼ tons per square inch.

If we turn to Molesworth's Handbook of Engineering Formulæ, and Hurst's Architectural Surveyor's Handbook, both of which are books purporting to supply all the latest information brought up to date

each year, we find the value of the constant to be applied in the formula for beams under transverse stress, given as 5 for English oak, 5 cwts. being taken as the central load required to fracture a standard bar, 12 in. long and 1 in. square; although the tensile strength of oak in lbs., in Molesworth's Handbook, is given as 17,000 lbs., which would give 8¼ cwts. instead of 5 cwts. as the central breaking load. Professor Rankine, in his "Rules and Tables," gives 10,000 to 19,000 lbs. per square inch, as the tensile strength of oak, and 12 to 14,000 lbs. for fir or pine.

Now let us glance at the crushing strength of timber, as given by different experimenters.

Rondelet gives the crushing strength of pine as 54 to 62 cwts. per square inch, and that of oak, as 45 to 54 cwts.

Tredgold took 36 cwts. for both.

Rennie gives the strength of pine at 14 cwts., and of elm, as low as 11½ cwts. per square inch.

Hodgkinson gives 92 cwts. for elm, 90 cwts. for oak, and about 54 cwts. for pine.

Lastly, I have here the results of some experiments made by Mr. Kirkaldy, on two logs 20 ft. long and about 13 in. square, one of white Riga and the other of red Dantzic fir, which show, in the first case, a resistance to crushing of 17·5 cwt. and in the last of 15·5 cwt. per square inch. Both balks failed by crushing, the lateral deflection not exceeding ·64 of an inch in either case.* These results approximate closer to those made by Rennie than any of the others.

Here is a mass of conflicting evidence, notwithstanding the apparent simplicity of the subject; and yet it is by no means as simple as it seems. The conditions were no doubt very different in each set of experiments; the apparatus employed was different, there were different observers, and therefore it is not to be wondered at, that the results arrived at differ. In fact the seasoning alone of the specimens would at once account for a great part of the difference; for green timber, from the moisture in it reducing the lateral adhesion of the fibres, has not more than half the strength of dry timber, and yet if artificially overdried, a considerable loss of strength would be the result.

With regard to the transverse strength of *timber* beams especially, though the same remarks apply to those of iron or any other material, what would appear to be an important element in their strength, though hitherto omitted from all calculations, is the lateral adhesion of the fibres to each other.

It is evident that, as the extension of the fibres varies according to their distance from the neutral axis of the beam, as the beam bends, the fibres, if free to move, would slide upon each other, which sliding is resisted by the adhesion of the fibres to one another, thereby increasing the resistance of the beam both to deflection and breaking. For instance, if a beam is supported at each end and loaded, it will assume the form shown in fig. A. If, however, it were conceived to be made up of a number of

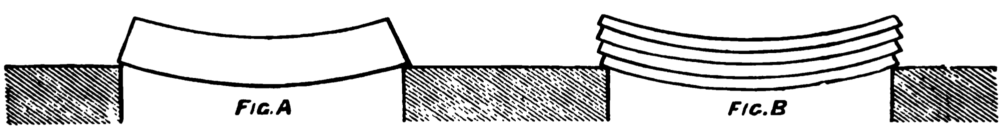


FIG. A FIG. B

thin layers, it would assume the form shown in fig. B, the difference being due to the resistance of the fibres to horizontal shearing, in addition to their resistance to direct tension and compression. The means of measuring this force is given by Rankine, at page 88 of his 'Applied Mechanics.' Mr. Baker, C.E., in his work "on the strength of beams, columns, and arches," pages 8, 9, 10, goes into this

* See Appendix 1.

subject and affirms that the neglect of this force in the beam, leads to errors of any amount up to 190 per cent., being little or nothing in iron girders, where the bulk of the metal is collected together in flanges as far as possible from the neutral axis.

IRON.—I now come to the subject, and a most important one, of iron. Notwithstanding the great advance which has of late been made towards a more perfect acquaintance with the properties of irons of different classes, and notably by means of the numerous experiments made by Mr. Kirkaldy, and the stimulus which has been given to the manufacture of high class irons, by the rival contests between iron guns and iron shields, it must be admitted, even by those who have made it a subject of special study, that there is very much yet to be learnt about iron; whilst, if we except a small circle, whose special employment has caused them to follow with interest in the track of every experiment which could throw any light upon the nature and properties of the material with which they are chiefly called upon to deal, there is a general lack of knowledge about the whole subject; besides much misconception, which the clear proof of practical experiment will alone be able to sweep away.

As a building material, iron is day by day forcing its way everywhere, and many, who not long ago, would have set their faces against its use in structures aiming at a high class of art, no longer hesitate to call in its valuable assistance in order to solve constructive problems which would be beyond the reach of wood, brick, or stone, at any rate within any reasonable limits of expenditure. Such being the case, it is essential that its properties should be thoroughly understood by all those who are likely to make use of it for constructive purposes, and that they should not merely order a girder, for instance, to carry a given load, leaving the designing of it to the manufacturer or his agent, whose interest it is to run up the weight, and hence the price, at the expense of quality and good workmanship.

It may safely be said that there is no material so dangerous to trust to, without a full knowledge of its behaviour under different conditions, than iron; whilst there is none which varies so much in quality, or in the manufacture of which there is more knowledge, experience, skill and care required, or which admits of more deception being practised upon the unwary, by unscrupulous and dishonest manufacturers.

Now I think, that, beyond the difference between cast and wrought iron, and the inferiority of the former, when exposed to the effects of sudden shocks, there is very little accurate knowledge on the subject of the properties and powers of resistance of different classes of iron under varying conditions of stress. Their behaviour under different circumstances, such as tension, compression, shearing, bending, torsion, either suddenly or gradually applied, varies so widely according to the description of the iron under trial, that the strongest proof which could be adduced of the necessity, for a far wider acquaintance with the subject is given by the ordinary formulæ in use for calculating the strength of iron girders, &c.

Turning to "Hurst's Architectural Surveyor's Handbook" as a likely source from which a formula might be taken for calculating the strength, or the requisite dimensions, of, say a plate girder, we find the following formula, given for ascertaining the central breaking weight of a plate girder, viz. :—

$$W = \frac{C\,A\,D}{L} \text{ in which}$$

A = area of tension flange in inches;
D = depth of girder in inches;
L = length of bearing in feet;

and a constant C, in this case taken equal to 6, is made to include such a *variable* quantity as the breaking strength of wrought iron per square inch of section, without one word of explanation as to the quality of iron to which this constant is specially applicable. Nor is the corresponding formula in Molesworth's "Engineering Pocket Book" one whit better. If we analyse the above formula, we shall find the tensile strength of the iron to which the constant is applicable is not more than 18 tons per square inch; for L being in feet and A and D in inches,

$$\frac{12\,L\,W}{2 \times 2} = C\,A\,D,$$

$$3\,L\,W = C\,A\,D,$$

$$W = \frac{C\,A\,D}{3\,L},$$

in which for C to = 6, the value laid down, the tensile strength must equal 18 tons.

Such formulæ, to those who are unable to unravel them, and see how they are arrived at, are but a delusion and a snare; they leave out of consideration the varying resistances of different classes of iron, and encourage the false idea that the strength of wrought and cast iron, or steel, may be safely represented by constant quantities.

In point of fact, we might ignore altogether the ultimate strength of a girder, since it is never, in practice, intended to be loaded so as to bring it anywhere near the breaking point; in addition to which the ultimate strength of iron is, by itself, no proof whatever of its suitability for the work it may be called upon to perform. What really would be quite sufficient for us to know is, the degree of elasticity combined with the elastic limit of the metal employed; the former being measured by the amount of temporary alteration of form the metal will allow of under a temporary stress; and the latter by marking the point beyond which, under uniform increments of stress, the visible work done, such as compression or tension, keeps sensibly increasing, instead of remaining uniform, and beyond which the alteration of form becomes permanent. When strained beyond this point, which is its elastic limit, the metal is permanently injured, and its power of resistance decreases in an accelerating ratio, until it finally gives way altogether.

The testing of iron, however, for its elastic limit is a matter of great delicacy, more especially as it is necessary to observe its reduction of area, or elongation, at the moment it reaches its elastic limit, and for this reason the breaking strength of iron is adhered to in practice, as giving, when observed in combination with its alteration of form, all the information required.

The degree of elasticity required in iron depends entirely upon the nature of the stress to which it is to be subjected, as whether the load upon a girder is to be dead or live, and how the latter is to be applied, namely, gradually or suddenly. If, then, we take proper steps to ensure the use of an iron sufficiently elastic for our purpose, and limit the stress to be put upon any of its fibres, so as to keep it well within the elastic limits of the particular iron employed, we may be sure of steering clear of any possible failures, except such as might arise from faulty design or faulty workmanship. Keeping these points in view, formulæ should be used in which the maximum stress to be put upon the metal takes the place of constants. Every one would then know the amount of stress they were actually putting upon the iron, and would take care that a proper class of metal, capable of safely resisting that stress, was made use of. Instead, then, of the formula already condemned, we might safely use the following viz.:—

$$\frac{W\,l}{4} = f\,A\,D \text{ or } W = \frac{4 f\,A\,D}{l},$$

in which W = load at centre of girder in tons.

l = span in inches.

A = area of tension or lower flange, in inches.

D = depth of girder in inches.

f = limiting stress in tons per square inch, which for railway bridges exposed to the sudden shocks of a live load, is fixed by the Board of Trade at 5 tons for tension, and 4 tons compression.

The load and span being known, the requisite dimensions of the girder may thus be readily found; or the girder being given, the load it can carry, subject to the particular limits of stress which may be laid down, can be ascertained. In this case the web of the plate girder, being thin, is not taken into account, but merely calculated to take the shearing stress; but in rolled iron girders, and other forms in which, from the amount of metal in the web, it would not do to neglect it, the bending moment due to the external forces must be equated with the moment of resistance of the beam, arrived at by finding the moment of inertia of the section of greatest stress, a process which is a little more troublesome. The girder having been designed, the remaining points to be attended to are to ensure sound workmanship, and an iron, capable, both as regards strength and elasticity, of taking with safety the stresses to be put upon it.

In order to insure our getting a suitable class of iron, it becomes necessary to have it properly tested. Let us suppose that some wrought iron tension bars are required, and that it was specified that the iron was not to break under a strain less than 23 tons to the inch, and supposing their actual breaking strength turned out to be 25 tons to the inch; that fact alone would be no guarantee that the iron was fit for the purpose for which it was required. If the elongation of the bars before fracture, or the reduction of the area at the section of fracture, was next to nothing, the iron could not be relied upon; though standing an exceptionally high tensile strain, it would be hard, brittle, and wholly unfit for use where it might have to resist the sudden shocks of a live load.

The elasticity or ductility of the metal must therefore be ascertained, in addition to its direct tensile or compressile strength. In testing wrought iron for tensile strength, this is most readily done by noting the reduction of area at the point of fracture, in addition to the force required to produce rupture. So that, in drawing up a specification for wrought-iron work, it is quite sufficient to specify that the iron shall be capable of bearing a given stress per unit of section, slowly applied, with a reduction of area at the point of fracture, equal to a certain percentage of the original section, depending on the quality of iron required; or, which amounts to the same thing, that the iron shall bear a certain stress per unit of fractured area. The best relations between the original and ultimate length of bars of iron, of different classes, broken under slow tension, or their original and ultimate sections of fracture, and their breaking strains, with regard to the different purposes for which the iron may be required, can only be ascertained by a most complete and careful series of experiments. I am, however, enabled to lay before you the results of a great number of experiments made by Mr. Kirklady, which have, so far as they have gone, been arranged by him in tables for the special use of the engineers of the Public Works Department in India, in drawing up specifications for wrought-iron work:—

In the Table irons of different well-known brands are classed under the letters C, B, D, E, F, G, according to their ultimate strength and elasticity. In addition to which there is a model clause for insertion in "Conditions of Contract," which, with but slight modifications would be applicable to any contract.

TABLE B.

SCALE OF TENSILE TESTS FOR IRON OF VARIOUS QUALITIES.

DESCRIPTION.	CLASS C.		CLASS D.		CLASS E.		CLASS F.		CLASS G.	
	Ultimate stress per square inch.	Contraction of area at fracture.	Ultimate stress per square inch.	Contraction of area at fracture.	Ultimate stress per square inch.	Contraction of area at fracture.	Ultimate stress per square inch.	Contraction of area at fracture.	Ultimate stress per square inch.	Contraction of area at fracture.
	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.	Tons.	Per cent.
Bars, round or square	27	45	26	35	25	30	24	25	23	20
Bars, flat	26	40	25	30	24	25	23	20	22	16
Angle and Tee or T..	25	30	24	22	23	18	22	15	21	12
Plates, lengthway ... Plates, crossway......	24 22 } 23	20 12 } 16	23 20 } 20½	15 9 } 12	22 19 } 20½	12 7 } 9½	21 18 } 19½	10 5 } 7½	20 17 } 18½	8 3 } 5½

N.B.—Classes A B are reserved for any special qualities of Iron which might be required at any future time.

SWEDISH BARS.

Ultimate Stress per square inch. } 22 tons. Contraction of area at fracture } 60 per cent.

TESTING CLAUSE TO BE INSERTED IN "CONDITIONS OF CONTRACT."

3.—The iron to be of such quality as to stand the following tests:—

ULTIMATE TENSILE STRENGTH PER SQUARE INCH.	Average Tons.	CONTRACTION OF AREA AT FRACTURE.	Average per Cent.
Bars, round and square	. . .	Figures from Table	. . .
Bars, flat	. . .	of Qualities to be	. . .
Angle and Tee	. . .	inserted in the	. . .
Plates, lengthway Plates, crossway	. . . } . . . }	blank spaces	. . . } . . }

4.—The Superintendent of Stores, or his deputy, will select materials representing 4 per cent. of the value, from which will be cut pieces 20 inches in length, and of plates and sheets 20 inches by 18 inches. These pieces, after being stamped at or near the ends with the Superintendent of Stores stamp, in addition to the maker's brand, will be sent to Mr. David Kirkaldy, Testing and Experimenting Works, The Grove, Southwark Street, London, S.E., to be tested and reported upon by him to the Superintendent of Stores.

The iron will be accepted, although under the above specified strain, provided the contraction of area at fracture is the same per centage higher, or in other words softer iron than that specified will be accepted.

In order to avoid expense and delay arising from rejection of materials, the attention of contractors is particularly requested to the foregoing tests, which will be strictly enforced in all cases.

The contractor will be required to supply and deliver the materials, but the cost of testing will be borne by the India Store Department.

There are many obsolete notions about iron, which still retain their places in specifications, such as "all castings to be of soft grey *cold blast* iron," and instructions laid down which are ignored by manufacturers, and any deviation from which could not be detected. All that is required with wrought iron is a compliance with the tests for strength and elasticity, and if these are satisfactory, it matters not, to the architect or engineer, how the metal has been manufactured, or what brand it bears. By limiting the stress to be put upon it, and then taking the proper precautions to insure getting a good and suitable class of metal, a great stride will have been made towards a sound method of dealing with iron for constructive purposes.

I might here mention that it is useless to specify that girders, when tested under a given load, shall not take more than a certain amount of permanent set, seeing that the manufacturer could, if he chose, take the permanent set out of them beforehand, by loading them with the test load, so that when tried after delivery they would show no permanent set whatever. I have here the results of two interesting experiments made by Mr. Kirkaldy, one on a wrought iron plate girder 23′ 2″ between the supports, which broke under a force of 44·1 tons applied at the centre; and the other on a cast iron girder, 18′ between the supports, which broke with a force of 45·19 tons; but as they will be embodied in my paper you will be able to examine them at leisure.*

In order to ascertain the quality of the cast iron used—for instance, in cast iron girders—the test bars usually specified to be cast at the same time, and from the same heating, as the girders themselves, should, if possible, be cast on to the girders, and only detached in the presence of the architect or engineer, or person appointed for that purpose. These bars are usually 2″ by 1″ and 4′ 6″ long, and are afterwards tested under transverse stress; but it is a question whether it would not be better to cast pieces to be tested under direct tension and compression.

Most people would, I think, condemn an iron which showed a crystalline fracture, as totally unfit to resist tensile strains or sudden shocks; and yet that crystalline fracture might be due either to the shape of the specimen experimented on or to the mode in which the breaking force was applied, for iron of a superior quality even, when broken by a sudden shock, will present a crystalline fracture, from the fibres not having time to draw out, and therefore breaking short across. For instance, here is a specimen of bar-iron showing a crystalline fracture with no diminution of area, having been torn asunder by the explosion of a charge of gun cotton; whilst this specimen, which is a piece of the same bar which I broke under a gradually applied tensile strain, gave a highly fibrous section, with a very great reduction of area, indicating a soft, ductile iron. I have also brought some armour bolts which have been broken under the shock of an eight ton hammer falling from a height of 3′ 6″. Those which were of a sufficiently soft, ductile iron, drew out before breaking, which they only did after ten or eleven blows: while those rejected on account of the hardness of the metal, broke, in some cases, with only one blow. That the best of these irons broke with a fibrous fracture is, however, no proof that under a more instantaneous rupture they would not snap without drawing out, and show a crystalline fracture. It is possible that if the most ductile of these bolts had been broken by the more instantaneous force generated by an explosion of gun cotton, the fracture might have been crystalline instead of fibrous.

Then again, the effects of different degrees of temperature upon the ductility of irons of different qualities is also a subject requiring further investigation. We often hear of the crystallisation of iron under the effects of frost, which means that it is apt to snap and show a crystalline fracture; but this is due merely to a loss of ductility, causing it to break without any extension of the fibres. We know that under great heat wrought iron looses its elasticity, but becomes perfectly ductile, regaining

* See Appendix 2.

its elasticity, but loosing its ductility as it cools. Different classes of iron no doubt lose their ductility at different degrees of temperature, when they become brittle and liable to break off short under any suddenly applied force. Experiment may in time give us some definite means of deciding the best class of metal to use in hot and cold climates respectively, though we know sufficient at present to prevent our using a hard metal where exposed to extreme cold. Wrought iron will also lose its ductility if, as is often the case in heating rivets, it is burnt by being left in the fire too long. A first class rivet when taken out of the fire and allowed to cool may be nicked with a cold chisel and then broken across by a blow of a hammer, and, if it has not been left in the fire too long, will show a fibrous fracture, but if burnt the fracture will be crystalline. If proper attention is not paid to this, much injury may be done to riveted work by too large a number of rivets being heated at a time, in order to save trouble. In riveting up the ironwork for forts a foreman of works is appointed specially to watch the riveting, twenty minutes being the utmost time 1″ or $\frac{7}{8}$″ rivets are allowed in the furnace; some are put aside to be tested, and any showing signs of burning are rejected. Other causes may perhaps also tend to reduce the ductility of iron, such as constant vibration and tension combined; but this, in the absence of any direct proof, is mere speculation.

Putting aside the quality of the iron as well as the nature of the breaking force, a crystalline fracture may be caused by any sudden diminution in the sectional area of a bar, such as is made by cutting a thread on a bolt, so that the same iron, exposed to the same stress, may be made to show a fibrous or crystalline fracture by merely altering the shape of the specimen.

The best shape to be given to different materials, according to the work they have to do, is another question as yet but little inquired into, but one which is of great importance in designing iron structures, as shown by Mr. Kirkaldy's experiments, and, practically, in what are termed the Pallisser bolts, for attaching iron plates to their backing. The use of a minus thread on these bolts, or a thread cut into the bolt, and so reducing its effective area between the threads, had the effect of concentrating the work done upon such a small length of the bolt that the fibres very soon reached their elastic limit, and the bolts gave way. This was remedied by reducing the shanks of the bolts so as to relieve the weak parts between the threads, by spreading the work over a greater length of fibres, thereby obtaining increased strength, with an actual reduction of metal.

Again, a law has been laid down, and universally accepted, derived from one or two experiments made upon iron of a certain class, that iron under tension extends $\frac{1}{10000}$ part of its length for every ton per square inch put upon it. Is this true for all qualities of iron, and for bars of all lengths? I think there is one person, at least, present who would, without hesitation, answer *No.*

Some few experiments have lately been made by Mr. Kirkaldy on long bars under tension and compression, and the results when published will be very interesting; but it is to be hoped that many more such experiments may be made, and on different classes of iron.

With regard to the resistance of wrought iron to compression we have very little satisfactory evidence, the whole question depending on the pressure under which different classes of iron begin to yield and sensibly alter their form; for if too short to bend or buckle as it sets up, the area of resistance is increased, and with it the force required to compress it; which has led to an erroneous idea, amongst some, that wrought iron is stronger under compression than under tension.

I will now leave the subject of iron, already drawn out to too great a length, with the hope that before long an accumulation of facts, derived from careful experiments, may clear up the many uncertain points connected with it.

STONE.—Passing on to another material, let us see whether we ought to rest satisfied with what we know about building stones.

Here again, the majority of experiments made have been upon very small specimens, such as small cubes under compression, whilst the recorded results vary with each set of experiments, according to the amount of accuracy capable of being arrived at by the machinery made use of, as well as the skill and care with which the experiments were made and recorded.

If we take a stone which has been more largely used perhaps than any other, namely Portland, we learn from Barlow that its crushing strength ranges from about 1,384 lbs. to 4,000 lbs. per square inch, whilst in the experiments made by this Institute, and recorded in your Sessional Papers for 1864, the mean resistance to crushing, per square inch, arrived at was, for 2″ cubes 2,576 lbs., for 4″ cubes 4,099 lbs., and for 6″ cubes 4,300 lbs.

According to Rennie its crushing strength may be taken as 3,729 lbs. per square inch, which has been followed by Molesworth in his "Handbook," whilst in Hurst's "Handbook" it is given as 2,022 lbs. per square inch.

Now the many varieties of Portland stone, apart from any different method or course pursued in making the experiments, and the amount of seasoning the blocks had undergone, all points which should be carefully recorded, would fully account for the manifest discrepancies between these results; in addition to which, the direction of the natural bed of the stone, which in a small block of Portland might escape detection, would no doubt make a considerable difference. For instance, turning to some experiments by Mr. Kirkaldy on the resistance to thrust of Doulting stone (a Somersetshire oolite),* which I believe to be the only known experiments on this point—if we except two on York paving and Bramley Fall stone, recorded by Rennie, in which the crushing strength both with and against the strata are given as precisely the same, a coincidence too good to be true—the advantage of laying the stones on their natural beds is considerable, increasing rapidly with the increase in height of the block, in proportion to its sectional area; which, I think, is what we should naturally be led to expect, if we look upon the block as approximating, more or less, according to the amount of lamination in the stone, to a number of thin columns placed side by side. More experiments, on a larger variety of stones, are much wanted to throw additional light on this subject.

With regard to the supposition that the crushing strength of stone increases with the size of the blocks under trial, there has as yet been too little proof put forward on which to lay down any law. In fact, the few experiments made by Mr. Kirkaldy, bearing on this subject, some of the results of which have been placed at my disposal, go to prove that there is no increase in the resistance to crushing, consequent upon increase in the size of the blocks.†

With regard to another of the oolites, namely Bath stone, there is, I think, a good deal of misconception, which a careful series of experiments would soon clear up. For instance, Farleigh Down, being a little more expensive than Box Ground stone, is very generally looked upon as the best and strongest description of Bath stone for outdoor use, and is accordingly very often insisted on in specifications, the fact being that, on account of the stone being more difficult to get out of the quarries, especially in large blocks, the price runs a little higher, whilst in strength or endurance it is not known that it can claim any precedence over Box Ground stone. From the experiments already referred to as recorded in your Sessional Papers, it would appear that Corsham stone is considerably stronger than Box Ground, though this is opposed to the results of other experiments. The durability of Bath stone mainly depends on its being placed on its natural bed, which can only be detected by an experienced eye, or by working the stone; though when not so placed it soon reveals the secret, especially where exposed to the weather, by its cracking and peeling away on the face.

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* See Appendix 3. † See Appendix 4

Much also depends on its being well seasoned, or air dried, before being put into the work, therefore the stone should only be got from quarry owners who keep large stocks of seasoned stone on hand. If quarried in the spring of the year, and stacked at open order during the summer weather, it is doubtful whether Corsham stone is not well able to resist the weather, though it is generally considered only fit for indoor work.

Artificial drying, which has sometimes been resorted to, should not be allowed. In one case a large quantity of picked Bath stone, which had been dried by heat, had to be condemned, and I believe led to a lawyer's bill, in consequence of the breaking up of the stone under exposure to the weather, owing, I fancy, to the unequal contraction and expansion of the dried and hardened surfaces, and the soft and green interiors of the blocks. I have seen stone, which had worn well when exposed to the weather, crumble away on being shifted to the inside of a house.

With regard to sandstones, the information contained in architectural and engineering handbooks is next to nothing, in fact in Molesworth the whole subject of sandstones is comprised in the information that their crushing strength is 5,000 lbs. to the square inch, which, being an easy round number to remember, might with equal reason be adopted as the crushing strength of all stones.

Very little is known with regard to the transverse strength of different kinds of stone, though there is no doubt that some are much more capable than others of taking a bending stress.

Stone is a material specially unsuited to resist any stress except compression, and it is the true appreciation of the nature of stone as a building material, by the almost exclusive use of it to the best advantage, namely, under compression, by the mediæval builders, that, to my mind, marks their great superiority, as scientific builders, over their predecessors of more refined classic ages.

In practice, however, we constantly find stone subjected to bending stress, and that further information under this head is required, struck me very forcibly some little time ago on seeing some stone stairs, two stories high, being carefully propped up with wood, many of the steps having split right across close up to the wall. The steps were feather-edged, of Portland stone, 11½" treads, and 6¼" risers, and had been exposed to the ordinary traffic of an office for about sixty-two years. The treads being much worn, a mason had been at work cutting them down at the top, preparatory to fixing an iron nosing, and filling the treads up level with asphalte, when the step he was at work on cracked close up to the wall, probably from the jarring caused by the strokes of the chisel; shortly after, several of the steps above cracked too, being no longer supported by those below, and being evidently unequal to do the work suddenly thrown upon them. Stairs with the steps only supported in the wall at one end are of constant occurrence, and serious accidents have sometimes occurred from their sudden failure.

Enough has been said, I think, to prove that more knowledge is required as to the special qualities of different kinds of stone, and their applicability to particular uses; but there is still another point about which there is not at present any certain knowledge, namely, to what extent the shape to which stones are cut, and the manner in which they are bedded, affects their strength. Some few experiments on these points have been made by Mr. Kirkaldy, at the instance of one of your Fellows; some of the results of which have, I believe, been already placed before you.

I have here the details of one or two interesting experiments to ascertain the effects of lead placed, as is frequently done, between the joints of cut stone columns, &c., with the object of distributing the stress uniformly over the beds of the stone.* The experiments were made upon circular blocks of Bath

* See Appendix 5.

stone, (Box Ground, and bottom bed Corsham Downs) 3 feet long by 10½ inches, and 15 inches diameter, or one set twice the area of the other; the lead being cut 2″ less in diameter than the beds of the stones themselves. The results point to the conclusion that lead so placed between the beds of the stones, reduces the bearing strength of a column to considerably less than that of a column, of only half its sectional area, in which the stones are completely bedded. On examining the sheets of lead, used in the joints, they seem to have been under compression at a very few points only, and not to have in any way tended to equalize the pressure over the area of the joints. These experiments also seem to indicate that raking out the joints of cut stone work, to save the arrises in case of any compression of the joints, when bedded in mortar, should not be carried too far. Such questions are, at any rate, worth investigation.

In all experiments upon stone, it is essential to know the exact description of the stone, the quarry it came from, and if possible the particular bed in the quarry. The time the specimen has been quarried should be stated, as some stones when green will stand very little stress, but harden considerably, in a longer or shorter time, when exposed to the air. If the specific gravity, or weight per cubit foot, of the specimen were given, it would afford some clue to the state of the specimens experimented on.

While on the subject of stone, I may refer to an artificial stone, widely used in the present day, viz., concrete. I think you will agree with me that a series of carefully made experiments on the strength of different kinds of concrete would be of great value, under varying conditions, as to the nature of the lime and cement used, the description of ballast, proportion of large and small stuff, and mode of mixing.

With good Portland cement, well burnt, and well ground, I should use with confidence for ordinary foundations, twelve ballast to one cement, provided I was sure of its being properly mixed; but with ordinary workmen, not properly drilled in mixing the materials, ten to one would probably be more advisable. It would be well to know how much the strength of concrete is affected by the different methods of mixing in vogue. For my own part I should insist upon the mixing being performed as follows:—A yard measure to be half filled with ballast, then the measure of cement to be added, and the yard measure filled up to the top with ballast. On removing the measure, the ingredients get partly mixed, and the cement does not get blown about so much as when placed at the top of the heap; it should then be turned over twice dry, and shoveled into a third heap, each shovelful being sprinkled from the fine rose of a watering can as it is thrown on the heap, whence it may then be removed to the trenches. This block has been broken with a pick out of a newly built dock wall, in which 12 to 1 Portland cement concrete, mixed in the manner described, was employed, and I think it is strong enough for any foundations. In making experiments, the mixing should be done in bulk, at least half-a-yard cube, being mixed at a time, and not in small quantities, which are more carefully prepared than would be the case in practice; and the blocks should be at least 12 inches cubes.

Passing from concrete to mortars, the results of some experiments made for the Patent Selenitic Mortar Company, show that in mortar made with common stone lime—Burham, or grey chalk lime, similar to Dorking lime, was used—3 sand makes a stronger mortar than only 2 sand, and stronger again than 4 sand; which is probably due to 3 to 1 being about the point at which more sand would weaken the cohesive and adhesive properties of the mortar to a greater extent than its setting or hardening would be promoted by increasing its porosity. With selenitic mortar, 5 sand was the best mixture to resist thrust, then 4, then 6 sand; but for adhesion and to resist tensile stress, 4, and then 6, and then 5 sand. From which we gather that 3 to 1 is the best proportion of sand to stone lime in common mortar, and 6 to 1 in selenitic mortar, since the latter gives a mortar pos-

sessing double the strength of common stone lime mortar. However in using the selenitic mortar at Chatham lately, 6 to 1 was not found to give such good practical results as 4 and 5 to 1, which is being now used. Although the 6 to 1 mortar set very hard, it was so short that it took longer to work, the loss of time outweighing the saving of sand. The proportions now being used are 4 to 1 for exterior work, and 5 to 1 in the body of the walls. Mr. Street has I believed had some further experiments made with the selenitic mortar in connection with the New Law Courts.

The best means of adding to our knowledge of Building Materials.

Having said thus much with regard to the present state of our knowledge of building materials, I pass on now to the concluding part of my subject, namely, the best means of adding to our knowledge, and placing it on a firm and unassailable basis.

Now I think it will be admitted that, in a matter so important to all as the possession of accurate information with regard to the strength and properties of building materials, all who have it in their power should do their utmost to further the carrying out of a carefully conducted series of experiments on an exhaustive scale, in order, if possible, once and for ever, to clear away all doubts and doubtful theories.

It was because I felt that the members of this Institute were, above all others, most deeply interested in the prosecution of such experiments, because I knew how much depended on their united action in this matter, and that were they each and all to assist, the whole question would soon be put upon a very different footing, that I undertook to read this paper here to-night.

Means for carrying out a complete series of experiments are placed within our reach, and of a description which I firmly believe leaves nothing to be desired.

Having often had occasion to visit Mr. Kirkaldy's Testing Works at Southwark, I have been struck with the immense advantage which a public—I might almost say a national—testing apparatus, open to all, such as he has provided, has over all private efforts, however numerous.

I am perfectly aware that attempts have been made to detract from the merits of the machine designed and erected by Mr. Kirkaldy. Prejudice and self-interest are always to be found arrayed against anything new, however successful it may be, in addition to which a certain amount of opposition is always to be expected from the machine refusing to give results consistent with the theories or interests of those who are consulting the oracle.

Different experimenters, with different objects in view, different modes of conducting and recording the experiments, different kinds of apparatus employed, often unscientifically constructed and erring in opposite directions, must, perforce, give different results, especially when recorded facts are read by the light of preconceived theories.

On the other hand, we have a single observer of facts, with a life-long training to the work, systematically recording the results given by a machine of most perfect construction, capable of testing materials in large masses, far beyond anything previously attempted.

Such an experimenter, who has made it the study of his life, is far more capable of recording and comparing facts with accuracy than one who has had no previous experience at such work. A comparison of the results obtained by different experimenters with the same machine even, is generally a hopeless task, from the absence of any uniform system of recording facts or conditions, such as the temperature, dryness, or exact nature of the specimen; if wood, from what part of the tree, and where grown; if iron, the alteration in form, &c.; if stone, the quarry, part of quarry, time since quarrying, &c.

I look upon Mr. Kirkaldy silently but powerfully working day by day in a special field of knowledge,

collecting and comparing facts, as one of the great levers, always at work to assist the progress of scientific knowledge. It is by men like him that the world at large is constantly being benefited, though too often without acknowledging their benefactors; by men who perceiving a great want, and the means of supplying it, devote the whole of their energies to proving the truth of the ideas they are impressed with, and persevere in working them out to a successful issue.

If all the members of this Institute, especially those who have large works on hand, were to cause but a few experiments to be made, in a short time numberless facts would be collected and compared, and the range of our knowledge of building materials would be rapidly extended.

The question naturally arises, who is to pay for the experiments suggested,—the builder, the architect, or his client? The answer is, neither of the three, but the manufacturer or producer of the material. For instance, let us take stone. On any large work being projected, stone merchants and quarry owners, without number, press the rival claims of their different stones upon the architect. Well, let all who wish to supply the material for the work send in specimens to Mr. Kirkaldy's works, say three 6″ cubes, three blocks 6″ by 6″ by 12″, and three 6″ by 6″ by 18″. Here you have the material at once to make experiments on, the cost of which would be defrayed by the successful competitor. Of course in the case of stone the selection would not depend solely upon the results of experiments on the strength of the material, since its weathering properties, &c., would have also to be considered. It may be said that only well seasoned and prepared blocks would be submitted. This could either be met by the architect employing some one at the quarry to select the stones out of which to cut the specimens, or by seeing that the stone supplied came up to the standard of the specimens submitted for testing. Such a system as this could be applied to all classes of materials, and the cost of the experiments would fall on the proper shoulders. It might possibly be as well if a committee of this Institute were to lay down, in consultation with Mr. Kirkaldy, the information which ought, in each kind of material, to be recorded; and if they were, as far as possible, to circulate amongst the members instructions with regard to the number and sizes most desirable for the specimens of various kinds of materials to be experimented upon. If some such course as that suggested were acted upon by all the members of this Institute, and by Civil Engineers as well, before long a vast number of experiments would place all disputed points beyond the regions of doubt and uncertainty, we should hear of fewer failures, and avoid endless little troubles, which are never heard of as failures, though in strictness they should be so classed, just as much as those which lead to serious results.

In conclusion, I can only say that if seeing assists believing, any gentlemen who take an interest in the subject I have been dealing with this evening, and who have not seen Mr. Kirkaldy's testing apparatus, would, I am sure, be amply repaid by a morning or afternoon spent in watching it doing its work; and I feel convinced that they will come away, unless they have a rival machine of their own, satisfied that it is capable of supplying with accuracy all the information they are likely to ask for. As I have already stated, one of the most important points to my mind is, as it were, the public character of the works, open to all comers and all materials, and containing complete and accurate records of experiments made with no aim or object but that of truthfully recording facts. I think that such an institution ought hardly to be left to the unaided enterprise of a single individual. I look upon its success as a matter of national importance, greatly affecting the safety as well as the pockets of the public at large, whether sitting in their houses, whirling along on railroads, or crossing the seas in ships. Numberless lives are year after year lost, life-long miseries caused, and thousands upon thousands of pounds wasted, from a want of proper knowledge of the strength and properties of building materials.

MAXWELL'S DIAGRAMS OF STRESS.

As before we can scientifically apply our knowledge of the properties and strength of building materials in designing a roof or other similar piece of framework, we must be thoroughly acquainted with the nature and amount of the stresses set up in the different parts of the structure, it has been suggested to me that I might with advantage draw the attention of those who are not already acquainted with the subject to a very valuable method of determining the nature and amount of these stresses, specially applicable to all framed structures, such as roofs, bridges, &c. I allude to what in England goes by the name of Professor Maxwell's method of diagrams—a method which is far better adapted to the ordinary uses of the office than such as involve mathematical calculations and a familiarity with trigonometry, which is not at the command of all.

It only requires a clear perception of the nature and effects of the different forces tending to d estroyequilibrium in any structure, and a certain amount of practice and careful ruling of parallel lines, and, by the aid of a scale and a pair of compasses, all the stresses may be accurately measured off the diagram, which, as will be seen, bears witness to its own correctness, since it cannot be completed, or the last line will not close the figure, unless all those previously drawn have been correctly laid off, both as to direction and length.

It is a system much in favour in Germany, but although special attention has been drawn to it in one or two of the professional papers, as also in a work entitled 'Iron Bridges and Roofs,' by W. Cawthorne Unwin, C.E., I do not think that it has met in England with as much attention as it deserves, though I know that several civil engineers have adopted it for working out stress diagrams of bridges and other structures.

Of course in common forms of roofs, &c., practical experience has supplied us with sufficient information to ensure our being on the safe side, though not always the most economical, without our setting to work to make a series of calculations; but when we indulge in designs of our own, or are dealing with materials not always used for the purpose we have in view, it is absolutely necessary, if we wish to avoid the regions of uncertainty, to find out the effects of all the forces which may conspire together to test our constructive skill; in addition to which, nothing could be more instructive to the engineering or architectural student than to work out some common examples, such as the one that I am about to use for the purpose of illustration, and see how far the dimensions of the different members, as arrived at by practical experience, agree with those pointed out by scientific methods of investigation combined with our knowledge of the materials dealt with, derived from experiment.

The case which I propose to take for the purpose of illustrating Professor Maxwell's system is that of a common wooden king post roof.

Example.—The first thing to be done is to determine the external forces tending to destroy equilibrium in the truss, then to see by means of our diagram how those forces are distributed through the different members of the truss, and finally to calculate the scantlings necessary to resist effectually the different stresses, making full allowance for the weakening of the timbers by cutting into them in making the several joints, which, moreover, should be accurately and carefully made, with a due regard to the nature of the stress borne at the joint, without which all our calculations would be of no use whatever.

Fig. 1

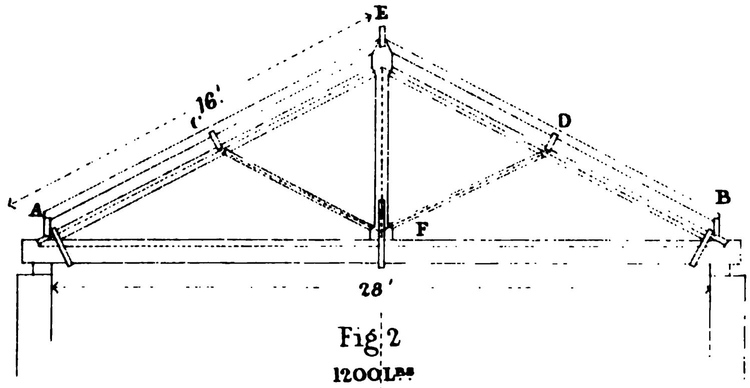


Fig. 2

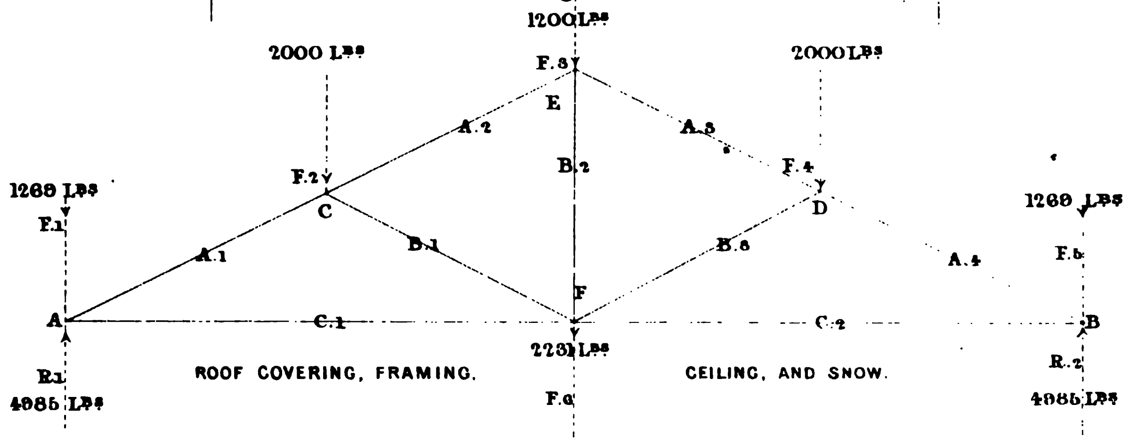
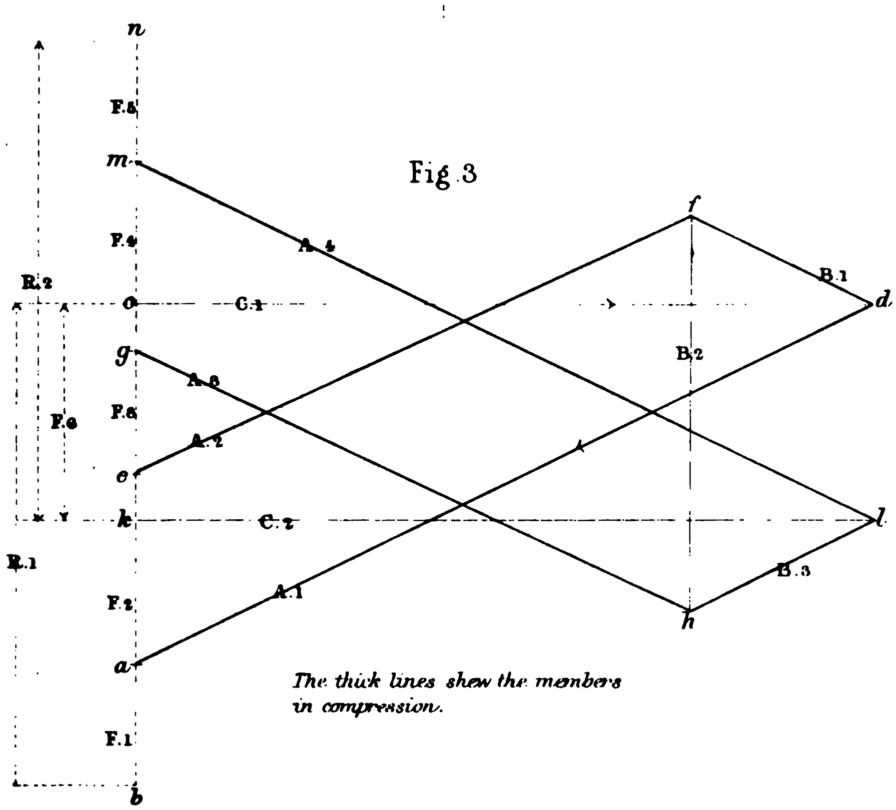


Fig. 3



The thick lines shew the members in compression.

Lithog^d for the R.I.B.A. by Kell Bros London, E.C.

Let fig. 1 be an approximate drawing of the truss, and let us assume the following conditions:—

Clear span of roof 28 feet.

Rise $\frac{1}{4}$ span.

Distance of trusses apart = 10 feet.

The purlins, pole plates, and ridge board are directly over the joints of the truss, and the common rafters are continuous from pole plate to ridge board, and 16′ long.

Weight of slating, boarding, rafters, and framing, except the tie = 15·5 lbs. per foot super of roof surface. To which may be added a possible weight of snow taken at 5 lbs. per horizontal foot super = 4·47 lbs. per foot super of roof surface; making in all 20 lbs. per foot super of roof covering.

Weight of tie, ceiling joists, and ceiling = 12.75 lbs. per horizontal foot super of surface.

Wind pressure, taken at a horizontal force of 50 lbs. per foot super, will be equal to a normal pressure, or a pressure perpendicular to the roof surface, of 30 lbs. per foot super.

Then the total external forces we have to provide for are—

Vertical forces = 9970 lbs. $\begin{cases}\text{Roof covering and snow } 2 \times 16' \times 10' \times 20 \text{ lbs.} = 6{,}400 \text{ lbs.}\\ \text{Tie, ceiling, \&c. } 28 \times 10 \times 12{\cdot}75 = 3{,}570.\end{cases}$

Wind normal to roof surface 16′ × 10′ × 30 lbs. = 4,800 lbs.

The wind pressure is taken as acting on one side of the roof only. The ordinary way of allowing for the wind is to treat it as so much additional weight per foot super of roof surface, which is manifestly incorrect, since the wind cannot possibly blow on both sides of the roof at one time, and the effects of its force being applied on one side only is more dangerous to the stability of the roof than if it were evenly distributed, producing opposite and counterbalancing forces.

The common rafters and tie beam being continuous beams, supported at the centre and both ends, and uniformly loaded, the loads will be distributed at the points of support, A, B, C, D, E, F, as follows:—*

Weight of the roof and snow, $\frac{3}{32}$ of 6,400 lbs. = 600 lbs. at A and B.
$\frac{6}{32}$ ditto = 1,200 lbs. at E.
$\frac{5}{16}$ ditto = 2,000 lbs. at C and D.

Weight of the Tiebeam and Ceiling $\begin{cases}\frac{3}{16} \text{ of } 3570 \text{ lbs.} = 669 \text{ lbs. at A and B.}\\ \frac{5}{8} \text{ do.} = 2231 \text{ lbs. at F.}\end{cases}$

Pressure of the Wind $\begin{cases}\frac{3}{16} \text{ of } 4800 \text{ lbs.} = 900 \text{ lbs. at A and E or B and E according to the direction of the wind.}\\ \frac{5}{8} \text{ do.} = 3000 \text{ lbs. at C or D according to the direction of the wind.}\end{cases}$

---

* The following show the proportion of the load borne by each support in the case of a continuous beam, uniformly loaded, supported at 3, 4, 5, or 6 points.

* $\frac{3}{16}$ $\frac{5}{8}$ $\frac{3}{16}$

$\frac{4}{30}$ $\frac{11}{30}$ $\frac{11}{30}$ $\frac{4}{30}$

$\frac{11}{112}$ $\frac{32}{112}$ $\frac{26}{112}$ $\frac{32}{112}$ $\frac{11}{112}$

$\frac{15}{190}$ $\frac{43}{190}$ $\frac{37}{190}$ $\frac{37}{190}$ $\frac{43}{190}$ $\frac{15}{190}$

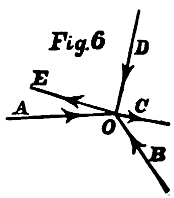
Having ascertained the nature and amount of the external forces, we have now to deal with their distribution through the truss; to do which we must first construct a line diagram of the truss, consisting of a line joining the centers of the abutments of the principal rafters, and of other lines drawn along the centers of the other members of the truss, as shown by the dotted lines on fig. 1. These lines will represent the lines of resistance in the different parts of the truss.

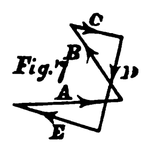
To simplify the diagram the braces may be drawn as meeting on the tie, without serious error, and in fact the lower the braces abut against the foot of the king, the nearer will the truss approximate to a perfectly braced frame. A separate skeleton truss should always be drawn on a good large scale, as is done in fig. 2, otherwise, if the lines are too short, it is difficult to take off lines parallel to them, and everything depends on the accurate drawing of the parallel lines.

The simplest plan is to ascertain first the stresses due to the uniformly distributed vertical forces, viz., the permanent load and snow, and then to arrive at those due to the normal pressure of the wind on one side of the roof only, by means of a separate diagram.

The vertical forces being symmetrically distributed over the whole roof, its weight is borne $\frac{1}{2}$ at A and $\frac{1}{2}$ at B; or, in other words, it produces reactions at the points of support A and B, equal to half its total weight, viz. $\frac{9970}{2}$ lbs. = 4985 lbs.

On fig. 2 let R_1 R_2 represent the direction and extent of the reactions at the points of support A B, due to the vertical loads only, and F_1 F_2 F_3 F_4 F_5 F_6 the vertical forces at the several points A, C, E, D, B, F. We have now got a diagram of the roof showing the vertical forces distributed over the different points of support, and the reactions at the walls due to those forces.





Now, it is known that if any number of forces act on a point, and are in equilibrium, they may be represented in magnitude and direction by the sides of a polygon drawn parallel to the direction of those forces, taken in regular succession. Thus if A B C D E, fig. 6, represent in magnitude and direction—the arrows show the direction—5 forces acting on the point O, they will also be represented by the polygon, fig. 7, in which the sides are laid down in the same order as those forces, and drawn parallel to them, the arrows pointing all the same way round the polygon, and in the same direction as the forces they represent. The direction of those arrows, as we shall see further on, indicate the nature of the forces, whether tension or compression.

Hence, if any number of forces act on a point, and all but two of them are known, both in direction and magnitude, and the direction of those two are also known, their magnitude and nature can readily be ascertained by laying down all the known forces, and completing the polygon by drawing two lines parallel to the two unknown forces. Now and then there may be three or more unknown forces, in which case they must be reduced to two by some other means, such as calculating out one of them, or omitting two which are evidently equal and opposite to each other. It may be as well here to observe that the polygon may be, as it were, only an imaginary one, or rather only a straight line; for instance, if two forces are acting on a point, for that point to remain at rest, the two forces must be equal and opposite to each other, and the diagram representing these two forces will consist of a line drawn parallel and equal to one of the forces, the other being represented by a line returning back on the first line to the point started from, thus showing that an equal and opposite force is necessary to produce equilibrium.

Fig. 3 is the closed polygon, formed by drawing lines parallel to the forces which have been ascertained to be acting at the points A B C D E F, Fig. 2. It is constructed as follows:—

Starting from one of the points of support A, we have two known forces, F_1 and R_1, and two unknown forces acting along A_1 and C_1, beginning with one of the known forces we draw *a b*, in the direction of, and parallel to F_1, and measured equal to 1269 lbs. on any convenient scale of parts. From *b* draw *b c* in the direction of, and parallel to R_1 and measuring 4985 lbs. on the same scale; then continuing round from *c*, draw *c d* of an unknown length, parallel to A F, and lastly from the starting point *a*, draw *ad* parallel to A C and cutting *c d* in *d*; then *c d*, *da*, will represent both in magnitude and direction, the stresses produced in A F, A C, and *a b c d a* is the polygon of forces in equilibrium about the point A; in which the nature of the stresses is shown by the direction of the arrows, which run in one way round the polygon. For if the directions of the forces are transferred to the corresponding members in fig. 2, those pointing towards the centre of the forces A will be in compression, and those pointing away from A will be in tension; A F is thus shown to be in tension, and A C in compression; and as they are marked respectively, A_1, C_1, *ad*, *dc* in fig. 3 should be marked in the same way, in order that the corresponding lines in the two diagrams may be recognized at once.

Proceeding to the next point C we have F_2 and A_1 known, and B_1 A_2 with the directions only known. On fig. 3, from *a*, set up $ae=F_2$ or 2000 lbs. Having now $ea=F_2$ and $ad=A_1$, and travelling round in the known direction of known forces, namely along *ea*, *ad*, from *d* draw *d f* parallel to C F, and from the point of starting *e* draw *e f* parallel to C E, cutting *d f* in *f*; then the stresses in C F, C E fig. 2 are represented by *df*, *fe*, in fig. 3. Mark them B_1 A_2 to correspond with their counterparts in fig. 2; *e a d f e* is therefore the polygon of forces in equilibrium about C, and the comprensile nature of the forces is shown, when their directions are transferred to fig. 2, by their all pointing towards C.

Passing on to the point E_1 (fig. 2), F_3 A_2 are known forces, and B_2 A_3 known in direction only. From *e* (fig. 3) set up $eg=F_3$ or 1200 lbs.; then starting with F_3 the direction of which is known, we have $eg=F_3$, and $ef=A_2$; from *f* draw *f h* parallel to E F, and from the starting point *g* draw *gk* parallel to E D, cutting *f h* in *h*, and closing the figure *g e f h g*, which is the polygon of forces in equilibrium about E, and the stresses in B_2 A_3 (fig. 2) are given by B_2 A_3 (fig. 3), the former being shown as before to be in tension and the latter in compression.

Taking the point F (fig. 2), next, B_2, B_1, C_1, and F_6, are the known forces, and C_2, B_3, known as to direction only; therefore beginning with B_2, the stress in which we know to be tensile, and therefore acting away from F_1, and following round B_1, C_1, we come on the stress diagram to *c*, from which point we must set off *c k*, in the direction of, and parallel to F_6,=2231 lbs. From *k* draw *kl* parallel to F B, and from the point of starting *h* draw *hl*, parallel to F D, cutting *k l* in *l*, and closing the polygon *h f d c k l h*, which accordingly represents the forces in equilibrium about the point F. The nature of these stresses in the different members about F can be ascertained as before.

Pursuing the same course, we get in fig. 3 the polygon *m g h l m*, representing the forces F_4, A_3, B_3, A_4 in equilibrium, about D, fig. 2; and finally the polygon *n m l k n* (fig. 3), represents the forces F_5, A_4, C_2, R_2 in equilibrum, at B (fig. 2), and the whole figure has proved its own correctness by the last line R_2=4985 lbs., when measured off the scale, closing exactly on the point *n*.

Had the figure been incorrectly drawn, or had the truss not been properly braced, the polygon would not have closed. The next thing to be done is to ascertain the distribution of the wind pressure on a fresh diagram, as fig. 4, and from it to draw the polygon of forces as shown on fig. 5, which is done in the same way as has been described at length for the vertical pressures.

Supposing the wind to be blowing from the left, the resulting stresses are ascertained thus:—

As already shown, the wind force is a uniformly distributed load, equal to 4,800 lbs. on one side of the roof only, and normal to its surface. Blowing from the left, as shown on fig. 4, it produces the forces F_7 and F_9 at A and E, each equal to 900 lbs., and F_8 equal to 3000 lbs. at C. F_7 is borne directly at A, producing a reaction equal and opposite to itself. The force C produces parallel and opposite reactions at A and B, equal respectively to $3000 \times \frac{BX}{AB} = 2000$ lbs., and $3000 \times \frac{AX}{AB} = 1000$ lbs.

The force at E produces parallel and opposite reactions at A and B, equal respectively to $900 \times \frac{BY}{AB} = 339$ lbs., and $900 \times \frac{AY}{AB} = 561$ lbs. The sum of these reactions at A are $R_3 = 900 + 2000 + 339 = 3239$ lbs.; and at B, $R_4 = 1000 + 561 = 1561$ lbs.

Then the forces acting at A are F_7 acting downwards, R_3 acting upwards, and the stresses in A F, A C.

On any convenient scale let O P (fig. 5) represent F_7, both in magnitude and direction, and P Q represent R_3; draw Q R parallel to A F, and O R parallel to A C. Then Q R represents the stress in A F, or C_1, and is in tension; and O R represents the stress in A C, or A_1, and is in compression. Mark these C_1 and A_1 in the stress diagram.

Similarly, the forces at C are F_8, A_1, B_1, and A_2; and the polygon is S O R T S—B_1 and A_2 being both compression.

The forces at E are F_9, A_2, B_2, and A_3; the polygon is U S T V U—B_2 being tension, and A_3 compression.

The forces at F are B_2, B_1, C_1, C_2, and B_3; the polygon is V T R Q V, whence C_2 is tension, and B_3 is shown to be a superfluous bar, having no value under this condition of loading, since C_2 meets the end of B_2.

The forces at D are A_3, B_3, and A_4; but B_3 is shown to be under no stress, therefore A_4 must be equal and opposite to A_3, and is compression as shown by U V.

Finally the forces at B are A_4, C_2 and R_4, and the polygon is U V Q U, in which, if the diagram has been correctly drawn, U Q accurately represents R_4, or 1591 lbs. on the scale of pounds.

When the wind is blowing from the right the stresses just ascertained are inverted, similar stresses being produced on the right half of the truss.

The stresses given by the diagrams must now be tabulated, and the maxima stresses obtained as has been done on the table of stresses.

All the stresses being now determined, they should be tabulated as shown on the table of stresses, the maxima stresses on each member being arrived at by adding them together, or by taking their difference, should the diagrams show that any of the members are subjected by one set of forces to tension and by another set of forces to compression, which in the present instance is not the case. The maxima stresses upon all the members of the truss being ascertained, their scantlings can now be determined if we know what resistance to tension and compression we can safely reckon on in the timber employed.

In the present case, taking the timber as Baltic fir, and the strength ordinarily laid down for such wood, the principal rafters should be $4\frac{1}{2} \times 4\frac{1}{2}$. The struts need not be more than $4'' \times 3''$. The tie-beam, limiting the deflection to $\frac{1}{40}$th of an inch per foot run, and adding 3″ to the depth for cutting away in framing, should be $4\frac{1}{2}'' \times 11''$; whilst the king need not, except for practical reasons, exceed $2\frac{1}{2}'' \times 2\frac{1}{2}''$, taking $\frac{13000}{5}$, as the safe tensile resistance of fir timber.

In order to show the application of Professor Maxwell's process to a more complicated structure, I have exhibited a plate on which is shown, by means of separate diagrams, the stresses set up in an iron

DIAGRAM OF STRESSES DUE TO WIND.

900 lbs

Fig 4.

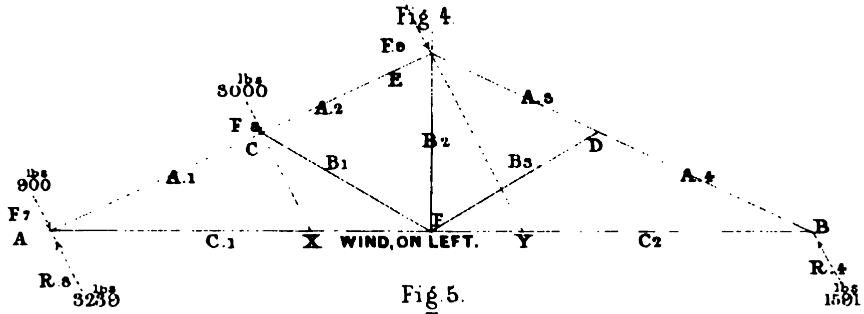
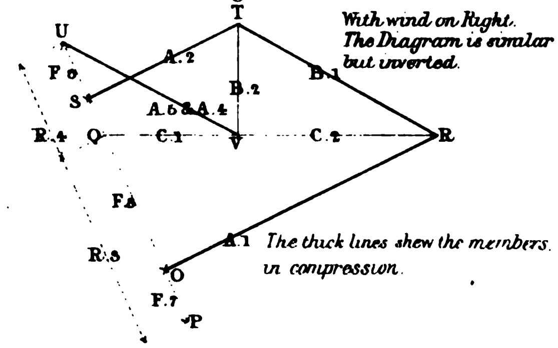


Fig. 5.



With wind on Right. The Diagram is similar but inverted.

The thick lines shew the members in compression.

TABLE OF STRESSES.

COMPRESSIONS + TENSIONS −

STRESSES DUE TO	ROOF Covering &c. and SNOW	WIND ON LEFT	WIND ON RIGHT	MAXIMA STRESSES
A 1	+ 8400	+ 4700	+ 3200	+ 13100
A 2	+ 6200	+ 2800	+ 3200	+ 9400
A 3	+ 6200	+ 3200	+ 2800	+ 9400
A 4	+ 8400	+ 3200	+ 4700	+ 13100
B 1	+ 2300	+ 3600	NIL	+ 5900
B 2	− 4400	− 1800	− 1800	− 6200
B 3	+ 2300	NIL	+ 3600	+ 5900
C 1	− 7600	− 5200	− 2200	− 12800
C 2	− 7600	− 2200	− 5200	− 12800

Lithog.d for the R.I.B.A. by Kell Bros. London E.C.

roof; in figs. 1 and 2 by the permanent load, in figs. 3 and 4 by wind on the left, the roof being in a normal condition, or neither expanding or contracting; and in figs. 5 and 6, 7 and 8, the wind on right and left, supposing one side of the roof to be fixed, and the other left free to move, and to be just on the point of moving under the influence of either expansion or contraction. Both of these examples have been selected from a number of others drawn out by Lieut.-Col. Wray, R.E., Superintendent of the Course of Construction at the S.M.E., Chatham, for instructional purposes, and, should you desire it, I can place at your disposal the working of the second example, as well as of that which I have just gone through. The way in which the wind force is treated in these examples is, I believe, as new as it undoubtedly is correct.

The great superiority of this method of diagrams over all others for ascertaining the stresses in the different members of a piece of framework is, as you have already seen, that it proves its own correctness, and any little error which may creep in is not being constantly carried on and increased, as is the case when separate diagrams are made for each centre of forces, in which case any little error at starting is sure to be carried on and magnified in transferring the measured forces from one diagram to another. Moreover any superfluous forces are pointed out in this system by the polygon closing without them, thus showing that they are doing no work.

A vote of thanks having been unanimously passed to Captain Seddon for his interesting paper, it was arranged that the discussion should be postponed until Monday the 27th of May.

Mr. DAVID KIRKALDY stated that he would be happy to show any Members of the Institute his Testing and Experimentary Works at the Grove, Southwark Street, S.E., on Saturday the 25th of May.

The meeting then adjourned.

List of Specimens exhibited by DAVID KIRKALDY, *to illustrate the various Stresses and the great variations in the Amount of Stress that can be applied, also in the Dimensions, in the Forms, and in the Materials, that can be tested by his patent Machinery.*

PULLING STRESS.

Fracture of 1 large wrought-iron roof link, 6¾″ × 1⅛″ × 21 feet; 12 steel and iron wires, from ·092 to ·25-inch diameter; 13 steel bars and plates of various sizes and qualities; 20 wrought-iron bars and plates of various sizes and qualities; 3 cast-iron bars; 2 riveted joints; 2 iron chains; 2 bolts and nuts; 2 copper bars; 2 brass locomotive tubes; 7 lead pipes; 3 tin and lead pipes; 1 piece 9-inch Manilla rope; 2 pieces leather belting English tanning; 2 pieces Swiss tanning; 2 pieces fir; 1 specimen of Portland cement; 1 selenitic mortar; 1 selenitic mortar joint; 1 common mortar joint.

THRUSTING STRESS.

Fractures 2 pieces English oak, 12″ × 12″ × 8 feet, and 9″ × 9″ × 8 feet; 2 pieces Dantzic fir, 9″ × 9″ × 8 feet. 3 Small oak and fir specimens; 1 12-inch cube red sandstone; 1 Doulting stone, 6′ × 6′ × 12 inches; 2 3-inch cubes of Charnwood and Ross of Mull granites; 10 steel and wrought-iron bars; 3 cast-iron and 4 gun-metal specimens.

BENDING STRESS.

Fracture 1 cast-iron girder, 4″ × 1¾″ × 9″ × 19½″ × 18 feet bearings; 1 fracture wrought-iron folled joist, 5″ × ½″ × 5″ × 10″ × 9 feet bearings; 2 fractures Dantzic fir beams, 13″ × 13″ × 12 reet bearings, and 6″ × 12″ × 12 feet bearings; 2 fractures Dantzic fir joists, 2½″ × 10″ × 10 feet bearings; 1 fracture wrought-iron axle; 4 steel and wrought-iron bars.

TWISTING STRESS.

1 Steel bar; 1 wrought-iron bar; 1 cast-iron bar; 6 steel and iron wires.

SHEARING STRESS.

1 Steel bar; 2 wrought-iron bars.

BULGING STRESS.

1 Steel plate; 1 wrought-iron plate.

BURSTING STRESS.

1 Lead pipe; 2 tin and lead pipes.

Total number one hundred and thirty-six specimens.

Results of Experiments to ascertain the resistance to a gradually increased Thrusting Stress of a Log of White Riga Fir and one of Red Duntzic Fir. _ Length exactly 20 feet, ends cut square. _

Scantling. White, end 13·5 x 13·0 _ Centre 13·0 x 13·0 = 169 sq: in Area: end 12·8 x 13·0 Red end 13·5 x 13·0, Centre 13·5 x 13·2 = 178 sq: in Area end 13·5 x 12·5.

Test No	Description	Total Stress in lbs: _ Depression inch. 20,000	30,	40,	50,	60,	70,	80,	90,	100,000	110,	120,	130,	140,	150,000
A 1349	'White Riga'	·032	·058	·083	·103	·122	·140	·158	·176	·194	·210	·225	·240	·258	·273
		Set								·010					·014
		Deflection horizontally								·34					·41
		Do vertically								0					0
1350	"Red Dantzic"	·035	·062	·088	·111	·133	·150	·170	·188	·203	·220	·232	·250	·263	·276
		Set													
		Deflection horizontally								·08					
		Do vertically								·10					

Test No	160,	170,	180,	190,	200,000	210,	220,	230,	240,	250,000	260,	270,	280,	290,	300,000	310,	320,	330,000	Ultimate Stress. Total lbs: Total Tons	Ultimate Stress. lbs p. sq: inch Tons p. sq foot
A 1349	·292	·307	·324	·340	·358	·371	·388	·403	·420	·434	·455	·473	·492	·508	·523	·540	·565	·642	331,260 lbs	1960 lbs
					·016										·022				147·88 Tons	126·04 Tons
					·47					·53					·64					
					0					0					0					
1350	·292	·302	·318	·329	·346	·354	·370	·384	·400	·414	·440	·469	·488	·507	·548	.....	.....	.....	309,120 lbs	1742 lbs
					·020										·033				138·00 Tons	112·02 Tons
					·19					·25					·47 08					
					·22					·29					·55 11					

A 1349 Gave way at knots 2' 9" off centre; 1350 at knots 0' 9"

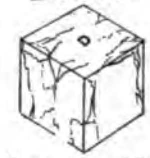
Results of Experiments to ascertain the resistance to Thrusting Stress of six cubes of Red Sandstone.

E 1893.

Bedded with Fine quarter inch thick

Test No	Quarry	Dimensions H. L. B.	Base Area.	Cracked slightly. Stress	Cracked slightly. p. sq: in:	Cracked slightly. p. sq: foot	Crushed, Steelyard dropped. Stress	Crushed, Steelyard dropped. p. sq: in:	Crushed, Steelyard dropped. p. sq: foot
E		Inches.	Square ins:	lbs	lbs	Tons	lbs:	lbs.	Tons.
1892.	"O" Ormside	5·98. 5·95 x 5·93.	35·28	85,270	2416	155·4.	118,160	3349	215·3
1891.	"O" do	5·95. 5·95 x 6·00	35·70	84,120	2356	151·5.	117,720	3298	212·1
1893.	"O" do	12·00. 11·96 x 12·02	143·76	346,620	2411	155·1	443,930	3088	198·6
				Mean	2394	154·0	Mean	3245	208·6.
1895	"D" Dufton	5·94. 6·00 x 5·98.	35·88	83,520	2328	149·7	93,870	2617	168·3
1894	"D" do	5·90 5·94 x 6·00	35·64.	81,270	2280	146·6	92,580	2599	167·1
1896	"D" do	12·00. 12·00 x 11·90.	142·80.	323,880	2268	145·9	358,230	2509	161·3
				Mean	2292	147·4	Mean	2575	165·6

E 1896.



Bedded with Fine quarter inch thick

Testing and Experimenting Works,
The Grove, Southwark Street, London. S. E.

David Kirkaldy.

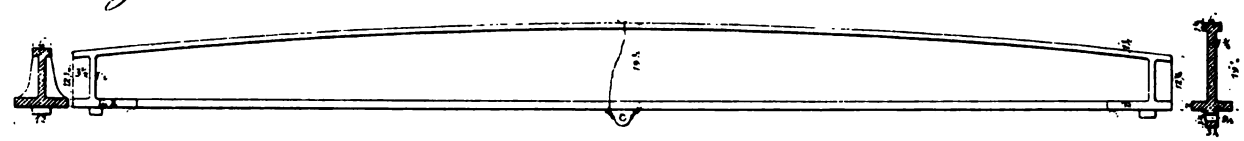
Lithog'd for the R.E.I.S.A. by Kell Bros. London E.C.

Results of Experiments to ascertain the resistance to Deflection Set and Rupture under a gradually increased Bending Stress of one Cast Iron Girder.

Distance between Supports 18′ 0″. Length of Girder 20′ 5″. Weight of Girder 1. 7. 3. 14 lbs:

	5 Tons 11,200 lbs:	10 22,400.	15 33,600.	20 44,800.	25 56,000.	30 67,200.	35 78,400.	40 89,600.	45 100,800	45.19 Tons 101,270 lbs: } Broke.
Deflection; inch:	·048	·172.	·296.	·418.	·538.	·677.	·828.	·980	1·17.	1·18 inch.
Set; inch.					·046		·087.			

Girder marked A. Test number D 560. Tested 21st April 1869.

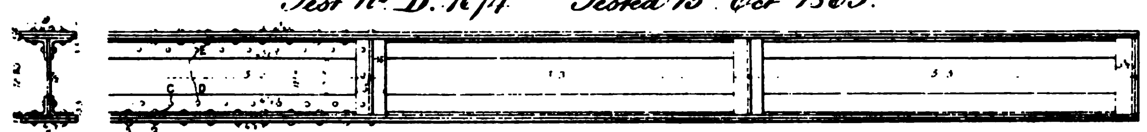


Results of Experiments to ascertain the Resistance to Deflection Set and Rupture under a gradually increased Bending Stress of one Wrought Iron Girder.

Distance between Supports 23′ 2″. Camber 0·55 inch. Length of Girder 26′ 6″. Weight 1. 13. 3. 21 lbs:

Stress in lbs:	20,000	25.	30.	35.	40.	45.	50.	55.	60.	65.	70.	75.	80.	85.	90.	95.	98,790 lbs: or 44·1 Tons:
Deflection; inch.	·212	·331.	·462	·598	·739.	·883.	1·03	1·19.	1·34.	1·50.	1·68	1·87.	2·08	2·34	2·74	3·46.	4·59 inches 1st plate snapped at A. 5·25 do. 2nd do. & angle broke at B. C. 6·20 do. Web plate & Angle D.E.
Set; inch.			·091.		·186		0·29.		0.43.		0·58.		0·80.		1·31.		

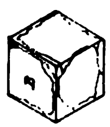
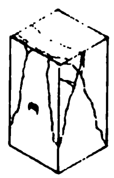
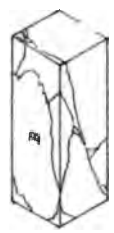
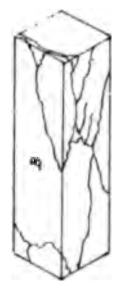
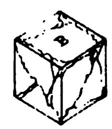
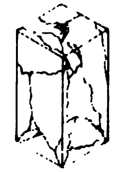
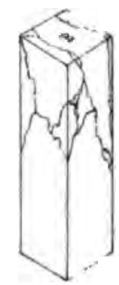
Test No. D. 1674. Tested 13th Oct 1869.



Testing & Experimenting Works. The Grove, Southwark Street, London: S.E.

David Kirkaldy.

Results of Experiments to ascertain the resistance to a gradually increased Thrusting Stress of eight pieces of Doulting Stone from Charles Trask's Quarries Shepton Mallet, Somerset.

Tested "Against" the Bed				Tested "On" the Bed			
F. 1674.	**F. 1675.**	**F. 1676.**	**F. 1677.**	**F. 1739.**	**F. 1740.**	**F. 1741.**	**F. 1742.**
6.04 × 6.05 = 36.54 super height 6 inches.	6.05 × 6.02 = 36.36 super height 12 inches	6.03 × 6.02 = 36.30 super height 18 inches	5.98 × 6.00 = 35.88 super height 24 inches.	5.98 × 6.00 = 35.88 super height 6 inches.	6.07 × 6.08 = 36.91 super height 12 inches	6.08 × 6.04 = 36.72 super height 18 inches	6.04 × 6.06 = 36.60 super height 24 inches.
							
Cracked slightly with 75240 lbs or 2097 lbs per square inch.			Cracked slightly with 62270 lbs or 1735 lbs per square inch		Cracked slightly with 69240 lbs or 1876 lbs per square inch	Cracked slightly with 72770 lbs or 1982 lbs per square inch.	
Crushed 89180 lbs or 2441 lbs per square inch.	Crushed 79620 lbs or 2189 lbs per square inch	Crushed 70570 lbs or 1952 lbs per square inch.	Crushed 65890 lbs or 1836 lbs per square inch.	Crushed 89380 lbs or 2490 lbs per square inch.	Crushed 83620 lbs or 2265 lbs per square inch	Crushed 79850 lbs or 2174 lbs per square inch.	Crushed 77040 lbs or 2105 lbs per square inch.

All bedded with Lime quarter inch thick.

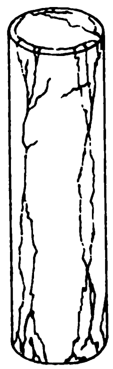
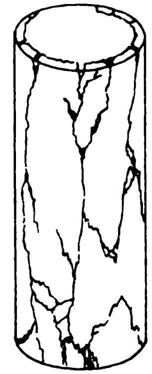
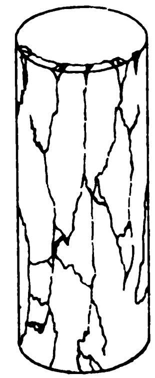
Testing and Experimenting Works, The Grove, Southwark Street. S.E.

David Kirkaldy.

of four Columns of Bath Stone.

"Box Ground."

"Bottom Bed Corsham".

E 577.	E 578	E 579.	E 580.
Diameter 10·41, 10·73 } = 10·57 inches	14·97, 15·03 } 15·00 inches.	Diameter 14·94, 14·98 } 14·96	10·55, 10·59 } 10·57 inches
Area 87·70 square inches	Area 176·71 Square inches	Area 175·68 square inches	Area 87·70 square inches
Length 35·06 inches	Length 34·52 inches.	Length 34·92 inches.	Length 34·92 inches
			
Bedded with four lbs. Sheet Lead cut 2 inches less diameter than Column according to instructions			Bedded with Pine quarter inch thick cut to same diameter as Column as always recommended by me.
61,730 lbs. or 27·56 tons 704 lbs. p. sq. in.	10,680 lbs. 570 lbs. p. sq. in. very slightly cracked	97,920 lbs. 43·71 tons 556 lbs. p. sq. inch. Very slightly cracked.	122,280 lbs. 54·60 tons 1394 lbs. p. sq. inch. Very slightly cracked at one end.
Cracked at both ends of Column and very rapidly extended the whole length, part of lead at one end not marked.	143,950 lbs. 64·25 tons 815 lbs. p. sq. in. Cracked in all directions. Lead at both ends uniformly marked.	120,730 lbs. 53·90 tons 687 lbs. p. sq. inch. Only one half of circumference cracked. Markings on lead prove that the ends had not been formed quite true.	130,810 lbs. 58·39 tons 1492 lbs. p. sq. inch. One end uniformly cracked all round, the other end but slightly.
1088 lbs. per sq. inch of lead area	1084 lbs. per sq. inch of lead area.		

These two experiments reveal the startling and important fact that a column properly bedded is very considerably stronger than one of double the area improperly bedded.

Testing and Experimenting Works.

The Grove, Southwark Street,
London S.E.

David Kirkaldy.

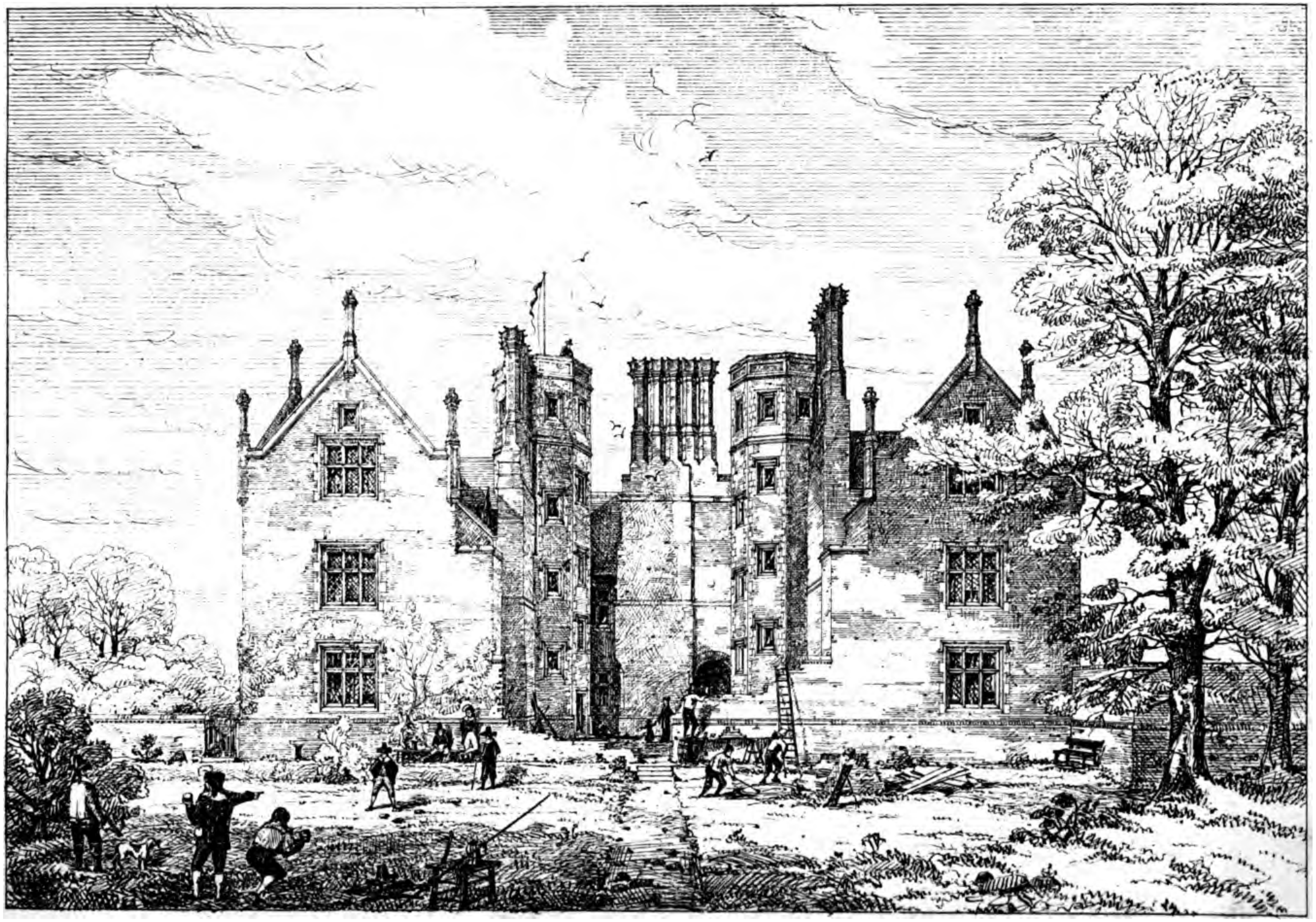


Photo-Lith.g.d for the R.I.B.A. by Kell Bros London E.C.

EASTBVRY MANOR HOVSE . SOVTH VIEW.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 8th April 1872, the following Paper was read, Edward I'Anson, Vice President, in the Chair :—

ON EASTBURY MANOR HOUSE, BARKING,

Being the DESCRIPTIVE ESSAY sent in with the Drawings for which Mr. H. W. PEEK'S First Prize was awarded to T. E. C. STREATFEILD.

THE manor of Eastbury (or Esbery, as it was first written*), in the parish of Barking and hundred of Becontree, is situated on the road to Dagenham, through Rippleside. It formed originally a portion of the lands of the great abbey of Barking. Soon after the Dissolution, in the year 1545, the manor was granted by Henry VIII. to Sir William Denham, Kt., a sheriff of London, by whom it was left three years later to William Abbot, who sold the property in 1557 to John Keele, and he, the same year, sold it to Clement Sysley, or Syseley. The building of the house has been ascribed to Sir William Denham, Kt.,† but there can be little doubt that this is incorrect, and that it is the work of Clement Sysley, later (about the year 1572), who was in possession much longer, and therefore had more time for what was in those days a large undertaking. This is confirmed to a certain extent by the tradition of a date on a spout at the south side of the house,† and in the hall as well; still more so by the style of architecture, which is thoroughly Elizabethan.

The house was fated to pass through the hands of many owners, for in 1607 or thereabouts it was sold by the Sysleys to Augustin Steward, from whom it went to the families of Price, 1628; Knightley, 1646; Sir T. Vyner, alderman of London, 1650; W. Browne, 1714; Welldale, or Welldon, 1740; Sterry, 1773; Newman, 1790; and Bushfield, 1802.‡ To Mr. Scott, the next possessor, is ascribed much of the destruction of the old internal fittings and arrangements, he having extracted floors and fireplaces;§ one or more of the latter may still be seen at Parsloes, a house in the neighbourhood, to whose owner, Mr. Fanshawe, they were sold.

Eastbury is now again in the possession of the Sterry family. Popular tradition connects the house with the Gunpowder Plot. It is even asserted to have been a haunt of the conspirators, but for this there seems no foundation whatever. It is worth noticing, however, that to this day excursionists, on their way to Rosherville and Southend, point to Eastbury as "Guy Fawkes' house." Traditions of this sort, extravagant as they may be, can generally be traced to some reality, however shadowy or remote. But in this case the fact of Guy Fawkes being regarded by the vulgar as the representative conspirator is quite sufficient to account for his being popularly associated with a house whose strongest claim to notoriety was its distant connection with the plot. For if Guy Fawkes' residence there is mythical, it is an almost undisputed fact that, at the time of the plot, Lord Monteagle rented the house from the owner, Mrs. Steward, who, it is known, did not reside at Eastbury, but in the parish of S.

* "Morant's History of Essex."

† "Grose's Antiquities," vol. i.

‡ "Transactions of the Essex Archæological Society."

§ I have since heard that there is no foundation for this, as Mr. Scott only occupied the house as a tenant.

Sepulchre, where she afterwards died. The following extract from the parish Register at Barking proves that Lord Monteagle resided in the parish at the time mentioned:—"1607. William, the sonne of Sir William Parker, Knighte, Lord Monteagle, baptized the 3rd day of December."

It appears that it was not unusual at this period for the large houses in the neighbourhood of London to be tenanted in this way. About the same time, William Mutbrowne's mansion, of Wakering Place in Barking, was let to the Countess of Sussex; and therefore, as it is known from the Register that Lord Monteagle, in the year 1607, lived in the parish, and the inhabitants of the other manor houses can be accounted for, while the owner of Eastbury was elsewhere, we may safely conclude that it was at Eastbury Lord Monteagle resided.

I am indebted for this information to Mr. King, of the Essex Archæological Society. The paragraph from the Register is also inserted in the account of Eastbury in "Lyson's Environs of London, 1796," vol. iv. In the former paper, which I sent in with the drawings of this house, I mentioned that it was asserted that the lease of Eastbury to Lord Monteagle had recently been discovered. I have since been making inquiries, and I find I was misinformed, and that there is no foundation for the statement.

In passing to a review of the house itself, and, first of all, the materials, it will be seen that it is, on the whole, in a fair state of preservation. The furniture and, to a great extent, the fittings, are entirely lost. The walls are throughout of brick, and, with the exception of the northernmost gable of the west front, where two or three cracks appear, are solid and good. The brickwork is executed in a sort of irregular English bond; but in some places it is difficult to find that there is any attempt at a regular bond at all. Black bricks have been introduced in patterns, in two or three places. It is worthy of remark that the bricks used vary in size, running from 7 in. to 10 in. in length, 4½ in. to 5 in. width, and 2¼ in. to 2½ in. in thickness. At Gale Street Farm, a building of apparently the same date, the brickwork resembles that at Eastbury, in the bond as well as the size of the bricks. This farm, which is about a mile and a half from Eastbury, close to Parsloes, is worth a visit, as the materials of a still older building have been used in its construction, such as stone quoins, moulded early English groining ribs, voussoirs of arches, which have been introduced at random in the brickwork. I was told by an intelligent bucolic that these are said to have come from the ruins of the old abbey at Barking. The interior of the house is unoccupied, and in a ruinous condition. The front of the building, with two gables, I learnt from the same source, was shaken down by the explosion at Erith some few years since.

To return to Eastbury—it will be noticed that the jambs and mullions of the windows, the string-courses, the front doorway, as well as the angles of the turret stairs, have been plastered in imitation of stonework. A casual observer might fancy that this plastering was the work of a later period, but I think there can be little doubt that it formed part of the original design; it has been thoroughly well executed, the plaster is good and finely composed, containing a little hair. It seems to be of the same consistency as the first, and probably the original, coating on the internal face of the walls. A further plastering appears to have taken place in the interior later, and it is on this, which is thicker and contains more hair, that the distemper paintings have been executed. As the painting probably dates from the time of the Stuarts (certainly not much later), a clear proof is obtained that the plastering beneath that on which they were executed, and which is differently composed, is of still earlier date. In this way the external plastering of the window-jambs, as it is similar to that inner coat in the interior, must of necessity be carried back to a date not long after the original building, and probably contemporary with it.

Another argument may be adduced from the fact that the house constantly changed hands since the time of the Syseleys; it may be assumed that the subsequent owners had scarcely sufficient attach-

ment to the place to induce any one of them to go to the expense of adding these quoins simply for the sake of appearance. Neither does Eastbury afford the only example of this; an old house—Porters—exists at Southend, which will be mentioned further on, where in the few remaining original windows the quoins and mullions are similarly of plaster. Some of the same work is to be found at Layer Marney Hall, near Colchester, and is described in a very interesting Paper by Mr. C. Forster Hayward, and published in the "Transactions of the Essex Archæological Society," vol. iii. part 1. After speaking of the general arrangement of the building, Mr. Hayward goes on to describe the exterior and the terra-cotta work in the parapets, which he says was at that period introduced into this country from Italy, where it had been in use some time. He says:—

"The material for all the Gothic portion of the edifice (except the stone jambs to the farm buildings, which, it should be observed, bear no traces of this new-born Italian feeling), is moulded red brick, so common in the eastern counties, and so worthily used in many noble buildings within a very few miles of Layer Marney, with which the usual ornamental work in black brick is used, forming diaper patterns over the surface. But in addition to this, in certain parts, a very fine plaster has been used in a manner showing the debased and false notions coming into vogue; for it is used to cover the brickwork, and is evidently intended to represent the stone jambs which would be naturally used in a country where stone was more common. However, it has long since been peeling off and looking exactly the sham it is; while the honest brickwork and terra-cotta only improve in colour day by day, though rather the worse for wear. I am bound to add, however, this plaster was admirably executed, and better than is usually done in these latter days when terraces of Roman temples have been produced by the mile in stucco grandeur and are now standing in stucco misery."

As it appears that stone was used in other parts of the building at Layer Marney, and perhaps was obtained without much difficulty, the use of plaster was all the more reprehensible, and was a base sham as Mr. Hayward describes it; but we cannot feel so strongly in the case of Eastbury, which it must be borne in mind is situated in a district where stone was scarce and costly. As the Gothic age, more honest in its use of materials, had then passed away, and an era of copying and importing foreign art taken its place, we cannot wonder that a builder, having designed his elevations in the bondage of classic rules, should seek to relieve the monotony of the one material to which he is confined in the absence of stone, by the introduction of what is pleasing to the eye, although offensive to the conscience.

Stone has not been entirely avoided at Eastbury, for it has been used for the fireplaces, only one remains, however, at present on the first floor of the Eastern wing. Three or four, as has been already stated, were sold to Mr. Fanshawe at Parsloes, where they may still be seen. These fireplaces, although they vary in size, are very similar in detail, and are all in the form of what may be called an angular Tudor arch with carving in the spandrel, and a carved frieze of Tudor roses in circles alternating with lozenges on the face of the stone above the arch. The roof, which is covered with plain red tiles, together with the doors, floors, &c., is of oak or chestnut. The principal rafters, which are 9 in. square, are framed with collars and tie beams, the latter act as binders to the second floor. The principals are 9 ft. apart and carry purlins 10 in. square, into which the common rafters are framed. There are remains of the lath and plastering on the under side of the collars and ashlaring of the principal, but nothing to show in what manner the ceiling of the intermediate spaces was carried. Those old doors which remain are simply two thicknesses of $\frac{3}{4}$ in. boarding nailed together, vertically and diagonally, hung in solid frames 14 in. by 7 in. on butt hinges, and in one case with a strap.

In the beautiful collection of sketches of Elizabethan houses by Mr. Twopeny, which that gentleman has kindly permitted me to see, besides the views of the house mentioned further on, there are drawings of a good ornamental plate to a door handle and an old lock, both at Eastbury. These

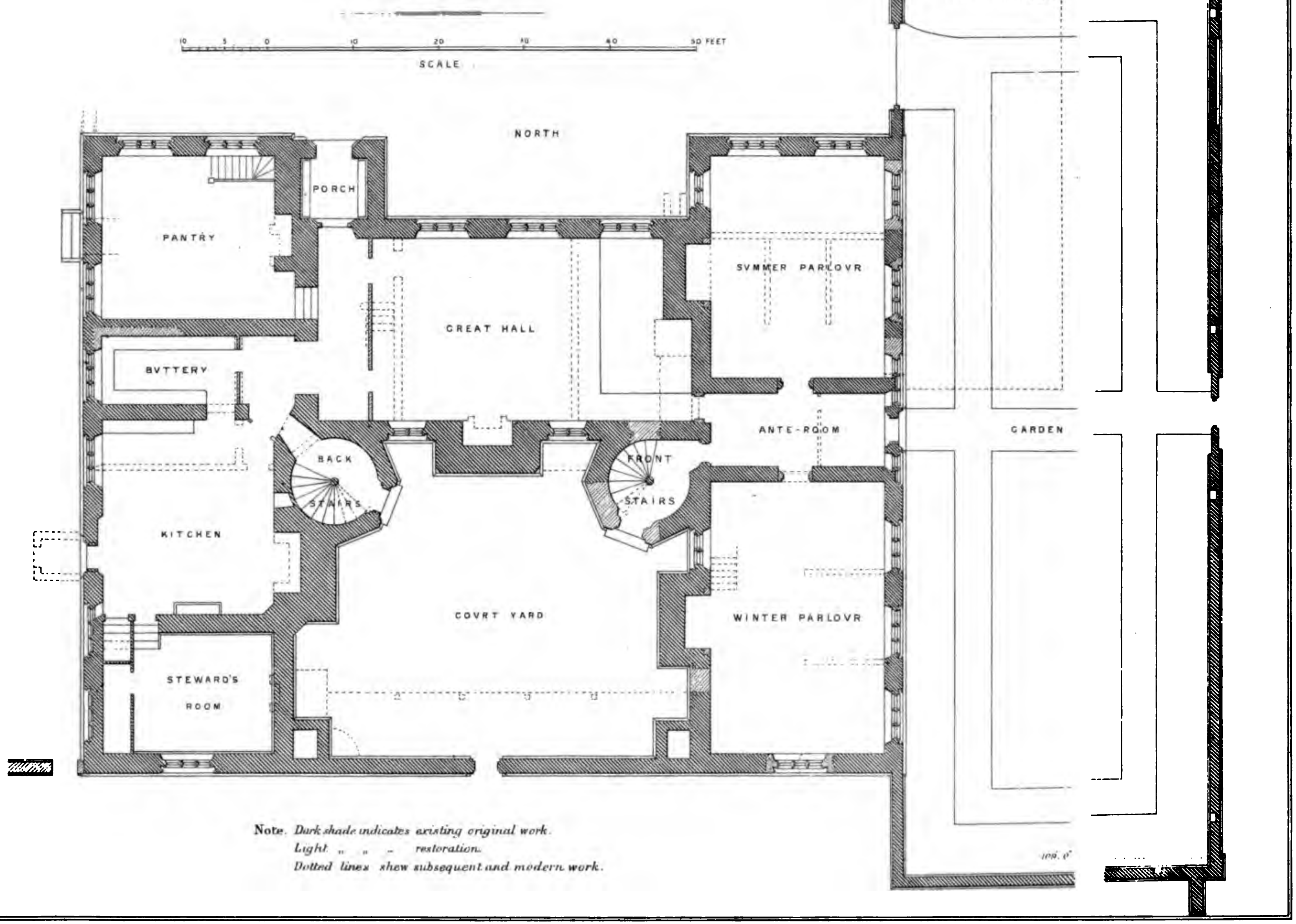
sketches were taken in the year 1828. It will be seen that the front staircase was destroyed the beginning of this century, the remaining one consists of solid oak treads triangular in section, morticed into a circular newel, with the ends let into the wall. With the interior of the house so altered and stripped it is difficult now to pronounce with certainty, but it appears that the small steward's room or parlour at the southern end of west wing was the only one whose walls were panelled. The Great Hall was plastered, also, probably, the remaining sitting rooms on the ground floor. On the first floor considerable remains of mural painting are still visible in a room above the Great Hall. This decoration, which is of later date than the house, probably Jacobean, is meant to represent wood in panelling thrown into rude perspective. It consists of a dado, above it semi-circular-headed panels containing one or two sea pieces in brighter colouring; over the fireplace a double panel shews a view down an avenue with a city in the distance. The same coat of arms is painted here on the stucco, as existed in the hall beneath; and is described in Ogberne's "History of Essex," as ermine a fesse, gules, between six moor cocks proper, borne by More of Cheshire; but it does not appear in what way this family was connected with Eastbury. One cannot congratulate the decorator of the period on his success, the work being as unsightly as the drawing is inferior. In Ogberne's "History of Essex" some more "frescoes" are mentioned as existing in a room of the east wing. They consisted of some military figures in niches of the time of James I., almost obliterated at the time Ogberne wrote. Three of the most perfect are represented as a drummer, a fifer and a soldier with his gun and rest. This history was published in 1814.

A reference to the accompanying drawings will best illustrate the house as supposed to be restored to its original condition. The ground plan shews the rooms as formerly appropriated together with the modern alterations. The building is, as it were, in three blocks, the centre being occupied (on the ground floor) by the Great Hall, the west wing by the offices, the east wing the living rooms, at the internal angles the two staircases. With regard to the west wing, an examination will shew that it has suffered less from recent alterations than the other portions of the building. The first room to the right on entering by the front door is at present used as a dining room. This probably served as a pantry formerly, and this name has been assigned to it in the accompanying plan. It will be noticed that the floor of this room is shewn on the drawings raised some two feet above its present level as floor of the modern dining room. The fact of the lights of the cellar windows being on a level with the present floor, and hence useless, also the position of the old cellar entrance on the west side, seems amply to warrant this arrangement. Next to the pantry, and between it and the kitchen, is the buttery or modern dairy, here a long space has been hollowed out of the wall nine inches in depth, which, there is some proof, was once occupied by a fireplace, as there are marks on the outside of an opening in the wall at this point as if for a flue, which evidently passed up the wall outside between the windows where the string course has been cut away and restored in cement as high as the parapet. While in the south-west views of this house, in "Lysons' Environs of London" and Ogberne's "History of Essex," the flue, with a small modern chimney pot, is distinctly shewn (these engravings are respectively dated 1796 and 1814). From the buttery, a doorway, now blocked up, leads into the kitchen, or rather that portion of it which has at a later period been partitioned off to form a larder. There is an external doorway to the kitchen with quite a modern porch. There are two doors side by side in the south wall, through the one by an ascent of four steps, you reach the steward's room, now coverted into a parlour; from the other a few steps lead down to the cellar beneath.

The old dining hall, which has since been sub-divided into an entrance hall, sitting room and bakehouse, was remaining and can be remembered forty years ago, with a wooden panelled screen

EASTBVRY MANOR HOVSE.

GROVND PLAN.



Note. *Dark shade indicates existing original work.*
Light " " " restoration.
Dotted lines shew subsequent and modern work.

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dividing off a passage at the front entrance, and the raised däis at the other end in about the positions indicated on the ground plan. This old hall, which was 37 feet long by 21 broad, was not open as was often the case to the second floor, but of the same height as the other rooms—viz., 11 ft. from floor to ceiling. The hall fireplace was somewhat similar in design to the one now remaining on the first floor of the eastern wing, but larger. It may, perhaps, be one of those in the kitchen or the servants' hall at Parsloes. Over it, on the wall, is said to have been painted the same coat of arms as has already been described, belonging to the "More" family.*

The eastern wing, now used for stables and a coach house, was divided originally into three rooms only—that at the northern end, called, perhaps, the "summer parlour," 25 ft. 8 in. by 20 ft. long, rather smaller than the "winter parlour" to the south, which is 32 ft. long. Although at present tenanted by horses, for whose comfort two doors have been broken through the walls at the end and, at the side into the courtyard, and all the windows have been blocked up, this room can be perfectly pictured in its original grandeur. The brick jambs of the fireplace remain with a bold semicircular relieving arch. In the centre of this wing is a small ante room. There are doorways from this besides those leading into the two parlours on either side, into the upper end of the Great Hall and into the turret stairs and hence into the courtyard, as well as an external doorway into the garden, disposed so as curiously to cut into a window in order to destroy as little as possible the symmetrical arrangement on the outside. The eastern turret appears to have been partially demolished the beginning of this century, and more completely so later on. It is described as in the act of being demolished in 1833;† and by another authority as having been pulled down before the year 1814.‡ A portion of the moulded brick handrail cut in the solid wall indicates the position of the steps. The first floor was arranged somewhat similarly to the one below, but the partition walls are not carried up in the eastern wing. There is next to nothing to show what was the arrangement of the second floor. The two garde-robes on the first floor, built at the angles of the courtyard, are not without interest as indicating the ideas of our ancestors on the neccessary arrangements of domestic economy.

Lovers of the ghostly who visit Eastbury, when they tread the creaking boards of the floors, and lose themselves in the deserted galleries, might naturally look to hear of legends of restless spirits haunting the scenes of their mortal strife. If so, they will be disappointed. Ghost stories at Eastbury, so far as I have learnt, there are none. It may be the tradition of them has died out with time, or lost itself in the frequent changes of owners. Yet there can be no doubt the mysterious architecture of the house at one place, lends itself marvellously to tales of the sort.

The large chimney stack over the hall fireplace has five shafts, three of these serve for the fireplaces below; but the other two are, to all appearance, sham. It will be seen, however, that they are built over the space between the eastern turret stairs and the Great Hall chimney breast, and carried by an arch turned at the level of the first floor. Above the arch, therefore—as it is almost impossible it should be solid—is doubtless a secret chamber. No entrance can be seen, but access was probably obtained from the flue above the fireplace of the first floor room. The two chimney shafts may have been designed with the double purpose of misleading an observer, and at the same time of ventilating the chamber.

"Porters," the old house near Southend, which has already been mentioned in connection with the plaster quoins, bears in many respects such a striking resemblance to Eastbury, that it is worth a

* I should here state that I am indebted for the information respecting the arrangements of the old Hall to a lady residing at East Ham, who herself can remember the facts.

† Clarke's "Domestic Architecture of the reigns of Elizabeth and James I."

‡ Ogberne's "History of Essex."

passing notice. The hall, porch and lobby together, with two staircases, occupy the central portion of the building, and unite the two wings, which appear, as at Eastbury, to have been used on the one side as offices and on the other as sitting rooms. At the angles are the staircases, just mentioned, not in separate brick turrets, but inside the building. One of these is comparatively modern, and possibly takes the place of another old staircase similar to the one remaining, which has solid wooden treads framed into a circular newel, as at Eastbury. A small balustered opening in the partioned wall of this staircase gives borrowed light from a narrow passage running between it and the external wall. Immediately at the top of the stairs is the entrance to a bedroom, which still retains its old doorway, consisting of stout planks in two thicknesses, furnished with the old wooden latch and bars. The door has a small circular hole in the centre, which can be closed from the inside, no doubt as a loophole for firearms; while in the floor of this room is a small trap leading to the kitchen below. In some circular panels high up in the wainscoting of the hall are some quaintly-carved heads of wood coloured. Five or six feet up the chimney of the fireplace is a small secret chamber. Among the stone fireplaces is one singularly like that on the first floor of Eastbury. Most of the external details, such as old chimneys, finials, &c., are lost; and where the old windows remain the jambs are plastered in imitation of stone, although the moulding is different to that at Eastbury, but possibly of the same date.

In passing to the exterior of Eastbury, it will be found on a close examination that the windows and dormers are not arranged as symmetrically as at first sight appears. On the west side, for instance, the spaces between the windows vary as much as 12 inches; the centre of the two most southern windows does not coincide with the centre of the gable over, as is the case at the north end of this front; neither is the small dormer gable in the centre between the larger gables. The same irregularities exist in the east front, while in the north front the parapets of the dormers are of a steeper pitch than the roof-line behind. There is at present nothing remaining of the gable finials, except a small portion of the panelled shaft forming the angle above the porch. The engravings in "Lysons' Environs of London," 1796, and in "Grose's Antiquities," 1780, shew them in different stages of decay. They are restored in the accompanying drawings partly from the illustrations of this house in "Clarke's Domestic Architecture," but more particularly in the case of the side finials from two views among some pencil drawings of the house by W. Twopeny, Esq., taken in the year 1828, in each of which appears a side finial complete, one on the north and the other on the east front. The curious termination to the capital was apparently hollow and of the form shewn in the elevations. The finials on the apex of the gables were lost at the time Mr. Twopeny's sketches were taken; but the two courses of bricks forming a finish to the chimney caps are clearly indicated in the large stack over the great hall. Ornamental chimney stacks, more or less similar in detail, may be seen at Newport and Redgewell, both in Essex, and at Norman Cross, Hants, and one almost identical, but of a rather later date, exists, or was existing till lately, at Langridge, near Halling, in Kent. Some light iron brackets, originally supporting a semi-round eaves gutter on the west side, are worthy of notice and are shewn on the elevations as restored. The old glazing remains in the south window of the west wing on the second floor, and consists of lead lights tied to iron stancheon bars with lead bands; there is an iron casement to open in the centre light. Flat iron rods, 3 in. by ½ in. thick, carry the heads of the windows, and the transoms; in the case of the latter the stancheons pass through the irons and brickwork, and are in one piece from the sill to the head of the window.

The enclosed space to the east of the house, now used as a kitchen garden, was probably the "green," or "lawn," and formed but a portion of the original pleasure grounds which extended also, no doubt, to the north of the house as far as the main road. It is remarkable that the present garden walls have not been set out square with the house, but incline on plan some 16 inches to the north. At the north-west corner is the main entrance to the garden, through folding iron gates quite simple

in design, but apparently of the date of the house. The garden wall is 15 inches in thickness and about 9 ft. in height, finished at the top with plain brick-on-edge, there being no remains of an ornamental coping.

The curious small recesses, the positions of which are marked on the plan, nearly opposite the ends of the paths, are 5 ft. 6 in. from the ground, 15½ in. in height, 12 in. in width and 10½ deep. and we may conclude from the following passage out of Lord Bacon's "Essay on Gardens," that they were intended to contain bird-cages. It must be remembered that Lord Bacon is describing a garden which, to use his own language, is to be "prince-like," as indeed may be assumed seeing his lordship begins by stating that the contents should not be less than 30 acres, including the "green in the entrance, the heath or dessert in the going-forth, and the main garden in the midst, besides alleys on both sides." He goes on to say:—"As for the making of knots or figures with divers coloured earths, that they may be under the windows of the house on that side which the garden stands, they be but toys: you may see as good sights many times in tarts. The garden is best to be square, encompassed on all the four sides with a stately arched edge. The arches to be upon pillars of carpenters' work of some ten foot high and six foot broad, and the spaces between of the same dimensions with the breadth of the arch. Over the arches let there be an entire hedge of some four foot high, framed also upon carpenters' works, and over every arch and upon the upper hedge over every arch a little turret with a belly, enough to receive a cage of birds."

In concluding my notice of this building, I will merely add that Eastbury Manor House, although it does not contain the elaborate detail or the features of interest which other mansions of the age can boast, may yet be described as a noteworthy example of Elizabethan architecture. Its present condition is much to be regretted. Not only are some of its most characteristic features partially concealed in the heavy growths of ivy, which must tend to hasten its decay, but an entire wing containing the former sitting apartments of the mansion has actually been degraded into stables and coach houses.

Every one interested in the history of our national architecture must feel gratitude to those who are sufficiently generous and enlightened to secure contributions to its materials from relics which daily become rarer.

The CHAIRMAN having invited discussion on Mr. Streatfeild's Paper,

Mr. H. W. BREWER, Visitor, said:—The irregular bond which is observed as existing at Eastbury House is also to be found in the north front of Hatfield House, which is rather remarkable, because the north front is the most important part of the building; the rest of the house shows both the Flemish and the so-called English bond. The irregular bond is also to be very frequently met with in the south of Holland and in Flanders. I remember noticing some very interesting examples of it at Roermonde and at Venloo, both in Dutch Flanders. In both these towns, the Flemish as well as the so-called English bond are found, but, as a rule, throughout Flanders the so-called English bond is in common use, while the Flemish bond is rarely to be seen at all. I think it very probable that the Flemish bond was originally used, because it was more easy to carry out circular work in that bond than in what is called English bond.

Mr. ROUMIEU, Fellow.—The paper we have heard is really so exhaustive that I have really little to offer in the way of remarks. I should wish, however, to call attention to the extraordinary squareness and perfect character of the timbers of this building. At one time Eastbury was used almost as a timber yard; people used to come there to purchase oak timbers, selecting them from the building, and pulling them down and taking them away afterwards. I never saw an old building with such perfectly square timbers; and, if we may judge from the largeness of the joists, the timber must have come out of trees of enormous magnitude. The staircases had large steps of solid oak.

Mr. WYATT PAPWORTH, Fellow.—I should like to ask whether the paintings that have been referred to were frescoes, or whether they were merely paintings in distemper; because fresco paintings of that date would be, I imagine, very rare.

Mr. STREATFEILD.—As far as I could see, they were merely painted in distemper.

Mr. KING, Associate.—I think that I could give Mr. Streatfeild the approximate date of "Porters." It was built by a citizen of London named Brown, of whose will I have the date.

Mr. STREATFEILD.—I believe it was built by the same architect as Eastbury.

Mr. KING.—It very closely approximates in date and style to Eastbury. I quite agree in the supposition that the paintings alluded to are frescoes.

Mr. GALBRAITH.—I should like to ask Mr. Streatfeild whether he does not think it possible that the niches in the garden walls were intended for plaster casts, as at Montacute Hall and Ham House.

Mr. STREATFEILD.—Possibly they might be, but it was suggested to me that they were for birdcages, and after reading Bacon's essay I came to the conclusion that there was something in the suggestion. I am told that similar nooks or niches are used in the north of Scotland for placing bee-hives in.

Mr. EASTLAKE, Secretary.—To what extent were the plaster quoins relieved from the surface of the brickwork?

Mr. STREATFEILD.—I can tell you that exactly, as I have a piece of the plaster in my pocket. It is about the sixteenth of an inch in thickness, not more.

Mr. MORRIS.—May I ask whether Mr. Streatfeild has compared previous illustrations of this house with his own drawings, as it has been treated of before, I believe, by several authors, by Mr. Clarke among others; and a gentleman going so carefully over the building as Mr. Streatfeild has done would have a very valuable opportunity of comparing it with the published works than mere ordinary readers. I think these illustrations are very valuable, but their value, of course, depends upon their accuracy. If this could be verified, it would give great interest to some of the works which have already appeared on this building. As to the recesses in the wall, in Shropshire I have seen stone lanterns, a kind of projection or small oriels thrown out from the face of the wall, intended for no other purpose than at night to act as a beacon for the country around. Whether the small recesses in question could have been intended for holding lights is a suggestion which just occurs to me.

Mr. EASTLAKE.—Were the window mullions of moulded brick?

Mr. STREATFEILD.—Yes, simply moulded with a hollow chamfer. The jamb of the windows was rebated, then there was another hollow, but no deeper moulding. The mullions have stood very well, but better, of course, on those sides of the building least exposed to the weather.

The CHAIRMAN.—I suppose we must all confess that the paper has been so full and elaborate that it has scarcely left room for any one to add anything to it. From my personal knowledge of at all events one building of this class, I believe that the plaster rendering described is of quite the same date as the building. I know of a building of the same age and character where the brickwork is of the same uncertain bond as at Eastbury, and where the mullions have been rendered with a plaster of the same kind. In Essex it is very common to have the cottages rendered with plaster and stamped all over with a simple and elegant impress. I once spoke to an intelligent plasterer on the subject, who does the same kind of work in Essex, where it is still practised, and he said it was simply done with road drift and chalk lime. It has certainly stood for two or three centuries perfectly well. I am sure that the best thanks of this meeting will be tendered to Mr. Streatfeild. We are very glad to see the gentleman who has carried off the first prize in the Peek competition come among us, and congratulate him on the paper which he has read to us to-night.

A BRIEF HISTORY OF BARKING CONVENT, ESSEX.

By PHILIP J. MARVIN.

THE convent of Barking, or Berking, derives its name, according to Morant, from *beonce*, birch-tree, and *ing*, meadow, the place formerly having been full of birch-trees. A different derivation is given by Lysons, who says that the name comes from *burgh-ing*, the fortification in the meadow, entrenchments being visible not far from the town. The convent was situated in the south-west corner of Essex, and in the hundred or half hundred of Becontre, which gets its name from a remarkable beacon supposed to have stood where Woodford windmill now is.

The nunnery was of the Benedictine order; it was founded in the year 675 by Erkenwald, second son of Anna, the seventh King of the East Angles; it was the second establishment of its kind in England (Folkestone being the first), and was dedicated in the first place to the Virgin Mary, and afterwards jointly to the Virgin Mary and S. Ethelburga or Alburgh, the first abbess and sister of the founder.

Erkenwald or Earconwald, the founder, was, according to Lysons, the first bishop who occupied the see of London after the building of S. Paul's by King Ethelbert; he was greatly celebrated for his piety, and Bede records many miracles wrought during his life and after his death; besides founding the convent of Barking, he established the famous monastery of Chertsey; he died in the year 685 when on a visit to his sister at Barking. In the reign of Stephen a magnificent shrine was erected to his memory in S. Paul's.

Morant says the first endowment is not to be found, but Lysons gives a facsimile of Hodelred's charter granting large estates to the abbey. William I. and most of the succeeding monarchs confirmed and added to the possessions until the time of Henry VIII.

The first abbess was Ethelburga, as already mentioned. Bede praises her holy life, and records miracles wrought in her time and afterwards; she was canonized, and was succeeded by Hildelitha, who governed the convent many years "with exemplary conduct;" she also was canonized. After this several of the abbesses were of Royal blood, as for instance, Oswyth, daughter of Edfrith, King of Northumberland, and Queen Ethelburga, wife of Ina, King of the West Saxons. The curious stratagem by means of which the latter induced her husband to give up his earthly crown is recorded at some length in William of Malmesbury's Chronicle; she was canonized. The next on the list is Cuthburga, sister of Ina; she died in the middle of the VIIIth Century.

There is a blank in the history of this abbey till 870, when it was burnt by the Danes: it remained desolate about one hundred years, being within the territory ceded by Alfred to Gormund the Danish King. About the middle of the Xth Century it was rebuilt by Edgar as an atonement for his having violated the chastity of Wulfhilda, a beautiful nun of Wilton, whom he appointed abbess; he restored the abbey to all its former splendour and endowed it with large revenues. After his death his widow Elfrida ejected Wulfhilda and took the government upon herself, but after the lapse of some twenty years, being seized with illness, she repented, and reinstated Wulfhilda, who seven years later, upon the Danes menacing England, retired to London, where she died; she was the fifth abbess who was canonized.

At the time of the Conquest the abbess was Alfgiva, appointed by Edward the Confessor. It is said that the Conqueror stayed at Barking while his fortress in London was being built. The next

was Queen Maud or Matilda, wife of Henry I. and daughter of Malcolm King of Scotland. The list then mentions Maud, wife of Stephen, as abbess on the death of Agnes in 1136. It is said she resigned in favour of Adeliza, sister of Pain Fitz John; during her government the Court was entertained at the abbey several days; this abbess founded the hospital at Ilford. Then comes Mary, sister to Thomas à Becket, and after her Maud, natural daughter to Henry II.

Stevens' list then gives Adelicia Valoniis, but the next in Dugdale is Christina de Valoniis. Then follow Sarah de Walebar, 1214; Sibilla de Walebar, 1215; Mabilla de Boseham, 1215; Maud or Matilda, natural daughter of King John, 1247; Christiana de Boseham, 1252; Maud Loveland, 1259; Alice de Morton, 1276; Isabella de Basinges, 1291; Matilda Grey, 1295; Anna de Vere, 1295; Eleanor de Weston, 1318. Stevens then gives Isabella de Weston, but the next in Dugdale is Jolenta de Sutton, 1329; Matilda de Montacute, 1341; and Isabella de Montacute, 1352: daughters of William Lord Montacute; then Katherine Sutton, 1358; and Matilda de Montacute, 1376, niece to the former abbess of this name.

It was at this time that a terrible inundation took place, the banks of the Thames at Dagenham giving way; other floods succeeded, and the income of the nuns was diminished 400 marks per annum.

The next abbess on the list is Sibilla de Felton, 1394—Stevens' list says 1404; and Cole in MS. additions to Willis's 'Mitred Abbeys,' mentions Anne Segrave as abbess in 1395, saying that Sibilla de Felton presented to Slapton rectory in 1407, but in 1395 a chantry was founded for one chaplain to say mass daily for ever at the tomb of S. Ethelburga, for the good estate of Sibilla de Felton, then abbess, &c.

In 1399, Eleanor Duchess of Gloucester died at the abbey, having retired there on the murder of her husband. In 1409 the nuns spent £2,000. in trying to repair the banks of the river at Dagenham, and their funds were so much reduced that no lady had more than 14*s.* per annum for clothes and necessaries. The next abbess was Margaret Swinford, 1419; then Catherine de la Pole, 1433, elected when only twenty-three years of age, daughter of Michael de la Pole, Earl of Suffolk.

According to Mr. Cole's notes, Margery Neville was abbess about 1449 or 1459; but the next on the list is Elizabeth Laxham, 1473; then Elizabeth Shuldham, 1479; Elizabeth Green, 1500; and lastly, Dorothy Barley or Barleighe, 1528; she surrendered her convent 14th November, 1539, receiving a pension of £133. 6*s.* 8*d.*; pensions were also assigned to some other of the nuns.

In Wright's 'History of Essex' I find that "The site of the conventual buildings with the demesne lands of the abbey were granted by Edward VI. to Edward Fynes Lord Clinton, who the next day conveyed them to Sir Richard Sackville; since that time they have passed through various families to the widow of the late Joseph Keeling, Esq."

"The manor of Barking continued in the Crown till 1628, when Charles II. sold it to Sir Thomas Fanshawe for £2,000., reserving a fee farm rent of £160., payable to the Earl of Sandwich."* The manor afterwards passed into the possession of the late Smart Lethieullier, Esq. Barking Abbey was one of the most important foundations in the kingdom; its yearly value was £1,084. 6*s.* 2½*d.*, now worth £21,684. 4*s.* 2*d.* Dugdale gives the annual revenue as £862. 12*s.* 5½*d.* There were only two which exceeded it in value, the nunnery of Shaftesbury in Dorsetshire, and that of Syon in Middlesex.

Until the year 1200 the King appointed the abbess, when by the Pope's interference the choice was vested in the convent and confirmed by Royal authority. The abbess was one of the four who were baronesses in right of their station; she lived in great state in her convent, having a large

* There is evidently some mistake here. In 1628 Charles the *First* was on the throne.—P. J. M.

household. There was also a prioress and two sub-prioresses. Dugdale quotes the directions concerning the creation of the prioress, also a most interesting MS. headed as follows:—"This is the charthe longynge to the office of the celaresse of the monasterye of Barkynge, as hereafter followeth." The spelling of this charter is very curious; the directions refer to the provisions of the convent and to the collecting of rents, &c., some of them being very quaint and rather vague, such as the following:—"And she shuld receive yerly xxiiis. iv*d.* of a tenement in Friday Street in London, bot it is not knowen wher it stonds;" also, "And she shuld receive yerly xxx*s.* of the rent of Tybourne, but it is not paid."

Two stones were found in the ruins of the abbey in 1720 and 1747; the first is circular, and has inscribed on it round a cross "Dns thomas bewford dux de excest an dni m°cccc°xxx°; on the other, long and smaller—

in harri bewford
ini . . . . wych.

The first is a memorial of Thomas Beaufort, Duke of Exeter, Earl of Dorset, &c., third son of John of Gaunt, the other of his only son Henry, who died young, or, as Mr. Lethieullier thought, of his brother Henry Beaufort, Bishop of Winchester, their sister Mary Swinford being abbess here at this time.

Lysons gives a ground plan of the chapel, supplied by Mr. Lethieullier, who had the site dug over in 1750, when he found Roman bricks in the bases of one of the columns, also a coin of Magnentius; he says the site was just within the north wall of the church yard, and the plan represents the chapel said to have been built in the time of Mabilla de Boseham, 1215; he gives the following dimensions: east to west, 170 feet; cross aisle, north to south, 150; choir, 60; width of choir and nave, 22; side aisle, 11; cross aisle, 28; diameter at base of columns, 8½; space between, 22. At the east end of the choir was the high altar, east of this was the lady chapel, the altar of the resurrection was in the north transept, that of SS. Peter and Paul in the south transept; the shrine of S. Ethelburga on the south, and that of S. Hildelitha on the north of the east end of the nave.

This is all the information I can find respecting the conventual buildings: nothing now remains except the gateway, illustrated by drawings sent in with a history of the abbey, of which this is an abridgment. This gateway is of simple perpendicular architecture, with diagonal buttresses and a turret staircase leading up to "the chapel of the holy rood, lofte atte gate edified (as expressed in an old record) to the honour of Almighty God and of the holy rood, that is there of right great devotion as it sheweth by great indulgens graunted to the same chapel and place by divers of our holy faders, Popes of Rome."

The parishioners wanted to put a bell over the chapel instead of one which they said was "crasid and fectief," though "persons of kunyng had serched it, and reported it not to be crasid and fectief."

This gateway is not vaulted; in the upper room or chapel is a carving of the holy rood, on one side of the east wall, but it is said to have been brought out of the church, and certainly does not fit its present place.

N.B.—The above Essay was sent in with the set of drawings illustrating Barking Convent Gateway, and for which Mr. Peek's prize (of £10.) was awarded to Mr. P. H. Marvin. Though not read at the General Meeting, it was ordered to be printed in this Sessional Paper.

Royal Institute of British Architects.

At the Ordinary General Meeting, held on Monday, the 27th May, 1872,
THOMAS H. WYATT, President, in the Chair:—

DISCUSSION ON THE PAPER BY CAPTAIN SEDDON, R.E., "OUR PRESENT KNOWLEDGE OF BUILDING MATERIALS, AND HOW TO IMPROVE IT," READ ON APRIL 22ND, 1872.

THE PRESIDENT having opened the discussion with a few preliminary remarks,

MAJOR-GENERAL SCOTT, C.B., Visitor, said,—There is a matter referred to in Captain Seddon's paper in which I am much interested, namely, the question of selenitic mortar, to which, as many of you may be aware, I have given considerable attention. There are one or two points in connection with the experiments I have conducted on this subject, on which it may be useful to others to have some information, and I should wish to explain, so far as I am able, why it is that selenitic mortar will carry so much sand. In dealing with limes by the selenitic method, the very different properties of pure and hydraulic limes and cements have to be borne in mind, for, whereas, the pure limes owe their setting properties, in a great measure, to the influence of carbonic acid gas existing in the atmosphere (so that in proportion, as the atmosphere has free access to the mortar joint, you get a greater amount of set), on the other hand, good hydraulic limes and cements especially give the best result when the joint is actually immersed in water, always supposing sand is not used in such great quantity that the mortar suffers disintegration before setting can take place. Now, between the pure limes, which owe their setting properties to the action of the atmosphere, and the eminently hydraulic limes and cements which owe their setting properties chiefly to the action of water, there are a variety of limes of intermediate properties, known as feeble and moderately hydraulic limes, which owe their action partly to the action of water and partly to that of the atmosphere.

In making experiments with selenitic mortar, whilst I have found that the best results were obtained by using lime possessing considerable hydraulic properties, of the same chemical composition in fact as Portland cement; yet remarkably good results are obtained also from limes of less pronounced hydraulic properties. When we mix such limes with sand, treating them in the selenitic way, I have found the best results to be obtained if the mortar is alternately exposed to the influence of air and water, so as to take advantage of both causes of set, and the strongest specimens I have met with are those which have been so treated. I think the cause of this may be readily understood, because the lime in the condition in which we use it for selenitic mortar—that is "tender-burnt" is more free to enter into combination with carbonic acid, but has not brought the silex into a condition in which it very readily passes into the condition of silicate of lime, not so readily, at least, as in Portland cement, which is burned at a high temperature; but though the silicating action is a slower one than it is in Portland, Roman, and Medina cements (which possess a more rapid power of setting in water), these cements are not so much benefited by the action of the air. The consequence is that selenitic mortar may be used with a larger amount of sand than such cements can be, if employed as mortar exposed to the air, and we find when so used that it has greater resistance than cements which, when immersed in water, possess the strongest setting properties.

I have found the best results to be obtained with selenitic mortar in air by using three or four parts

of sand and one of lime, but we secure remarkably good results with six parts of sand to one of lime; and selenitic mortar with the larger proportion of sand, used in ordinary masonry and brickwork, has a greater resistance even than Portland cement under similar conditions. This arises from the nature of the setting action in selenitic mortar, which consists, as I have said, partly in the silicating agency between the lime and silex, and partly in the influence of the atmospheric air. In proportion, therefore, as you mix larger quantities of sand with the seleniticised preparation of lime, the mortar is more porous, and the air getting more freely into it assists it more than it can assist Portland, to which the carbonic acid gas in the air is less advantageous. We have found, as I say, that up to three parts of sand Portland cement has a greater resistance than selenitic mortar, but when you increase the proportion of sand, in each case, beyond this, you get greater strength out of selenitic mortar than out of Portland cement, a fact well worth the attention of architects.

It will, perhaps, interest the meeting to hear something of the supposed effect which is produced by the addition of a small quantity of plaster of Paris introduced into unslaked-lime mortar. As you are aware, pure lime, or ordinary hydraulic lime, mixed with water heats up and falls to powder, and after it is slaked it must be mixed with more water to form the powder first produced into a paste. On the other hand, if you previously mix with the water used a small quantity of sulphate of lime, you will find that the lime will set with its original density, and without slaking or swelling. The late General Pasley said, "If we could get lias lime to set with its original density, we should give to it the strength of cement," and the accuracy of this observation is borne out by the action of seleniticised lime. The small quantity of plaster of Paris which is thus mixed with the lime (not exceeding more than four or five per cent.) has some extraordinary influence upon the particles of lime, which prevents their combining with water rapidly, and the lime sets without increase of bulk, and, consequently, with the density of the ground lime employed; and one of the reasons for the great endurance of selenitic mortar is the greater density with which the mortar sets, than where its bulk is increased two-fold or upwards by slaking. As to the cause of this selenitic action, as I have termed it, I do not think it has met with the attention from chemists which the subject deserves. It has now been before them for twelve or thirteen years, and up to the present time, with the exception of a German chemist of the name of Schott, and with the exception of Professor Abel, I think nobody has made any careful experiments on the subject, or attempted to give an opinion concerning the matter. When the process was first proposed some fourteen years ago, a learned chemist said it was making plaster of Paris in a round-about way (a remark which shews a total misapprehension of the subject), and that is all the notice the question has had in a public form from chemists, until Professor Abel reported on it last year amongst the scientific inventions at the International Exhibition.

My own idea on the subject is, that each particle of lime having sulphuric acid in reach of it sets as a particle of plaster of Paris; that as soon as one particle has set, and combined with its equivalent of water, it passes its dose of sulphuric acid to the next particle, and that also sets, as plaster of Paris, as soon; that is, the mass sets by a sort of contact action. It is known to chemists that when bodies are in a peculiar state of change (like that produced by the fermenting action of yeast for instance) they are apt to rob their neighbours of the substances that belong to them and transmit them to others. One particle of lime, in the act of combination with its equivalent of water, seizes a little sulphuric acid at the same time, and, having used it, passes it on to its neighbour, and thus contact action goes on through the mass. We have proof of this from the fact that if lime is merely mixed with plaster of Paris, and exposed to damp, the lime will slake in the ordinary way; there is not enough water present to allow the sulphuric acid to be conveyed from one particle to another. If,

again, you make an imperfect mixture of grey lime and plaster, and mix these ingredients into mortar, and allow the mortar to commence setting, you will perceive that the selenitic action clearly proceeds from the centres, afforded by the particles of plaster of Paris which you see dotted in the mixture. As the grey lime when it slakes changes colour, you may see round each particle of plaster of Paris a little yellowish green patch, beyond which the selenitic action does not proceed, and ceases to influence the lime. To make the mortar successful, the mixture must be sufficiently perfect to enable this contact action to travel through the mass.

The PRESIDENT.—As to the selenitic action upon concrete, some builders have objected to it on the score of its not setting so soon as the common concrete. In one case I know it was put on to a depth of 23 feet in trenches. We tried it on a small scale first. Whether it was that the atmosphere got more thoroughly to it above ground I do not know, but it did not set quickly at the bottom of the trench.

Major-General SCOTT.—The reason for that is easy to see. What contractors and others usually term setting is really only the slaking and warming and drying of the lime, and nothing more. After that slaking has taken place, by degrees you get a certain partial induration from ordinary grey lime; but unless it is water-setting lime, you do not get any great induration. In the case of the selenitic mortar, the heating action and slaking is controlled and delayed, and though it does not dry up so quickly as lime used in the ordinary way, and therefore appears to the builder to set more slowly, yet if the slow drying mortar is examined at the end of a month or two (more particularly when under pressure), the results are surprisingly good in comparison with those which lime, as ordinarily treated, yield.

Professor KERR, Fellow.—There is another process which may be in the recollection of some present, which purposed to effect results similar to those which General Scott has mentioned, viz., the process of Mr. Westmacott, which was laid before this Institute, six or eight years ago; and I should like to ask General Scott whether he has given any attention to that process, and whether he can account for the peculiar action that takes place therein. Mr. Westmacott stated that if you pull down a very old wall, you will find the mortar adheres to the stones, provided those stones contain carbonate of lime, with remarkable tenacity. Why is this? Mr. Westmacott's theory was that the tenacity of the mortar must arise in some degree from the communication of carbonic acid from the stone to the mortar where in contact with the stone; and proceeding upon that theory, he advised this plan—Give me a certain measure of lime, no matter of what kind, and a certain measure of ground chalk, not as in the present case, plaster of Paris. I think the proportions were equal; at any rate the proportion of chalk was much more than the five per cent. now in question. I will mix these, he went on to say, with a large proportion of sand (I believe the proportion of sand was something like four or five times the bulk of the combined proportions of lime and chalk); and if you mix your mortar in that way, you will be astonished at the induration that will be effected. The chemical theory of this matter, I believe, was that the carbonic acid was communicated from the portions of chalk to the mortar, and a process of induration thus set up very rapidly. The setting of the mortar at any rate was very quick, and the degree of induration of the mortar when set was surprising. Certainly, I have seen specimens of mortar prepared in this way which were almost as hard as Portland stone. These specimens were, no doubt, manipulated with what may be considered the equivalent of pressure; but for all that, the stone-like appearance of this common lime mortar was to me astonishing. It was stated, I believe, that if you used this material for plaster work, you might put on the three coats almost in a single day; but he did not engage that you could paint on it as you can upon Parian cement when finished; but to my own knowledge he did finish, in the way of experiment, on a small scale, plaster work in two days. I am bound to say that an eminent chemist told me that in his opinion

the carbonic acid could not possibly be communicated from the particles of chalk to the mortar. But when I asked him if he could account for the facts by any other means, he said he could not. General Scott may, perhaps, be able to inform us why he has any opinion upon the subject?

Major-General Scott.—With respect to the adhesion of mortar to different surfaces, I think no doubt, whatever the cause may be, the adhesion of mortar to lime-stone is superior to that which you obtain with granite or other surfaces of equal smoothness. Colonel Pasley made experiments on this subject, and the adhesion of mortar to carbonate of lime was found by him to be very strong. From Professor Kerr's remarks I think there must be in his mind an idea that there is an analogy between the so-termed selenitic action I have spoken of, and Professor Westmacott's idea that the carbonic acid gas of the limestone would leave the stone and go to the lime. I alluded to the active condition in which lime exists, in the case of selenitic mortar, at the moment at which it is becoming hydrated. You have the lime here in a condition of change which is no longer the case when once it has united with water, and has already become the hydrate of lime of ordinary mortar. Now in the case proposed by Professor Westmacott there would appear to me to be no reason for any change taking place; both the carbonate of lime and the hydrated or slaked lime which he employed were both in a stable condition, very different from that of the quick lime employed in preparing selenitic mortar. I cannot, indeed, see that there would be any possibility of the carbonic acid gas leaving the limestone and combining with the slaked lime, whilst I can see a very sufficient reason for the sulphuric acid in a condition of solution passing to the quick lime. Chemistry offers many analogous phenomena. The two cases are not at all similar: I can, however, understand when I am told that pressure was exerted by Professor Westmacott in his experiment that he got much greater resistance than with ordinary specimens of mortar. A small amount of pressure makes a mortar joint much stronger; therefore, experiments with bricks merely put together with mortar do not give an idea of what the mortar will do under pressure.

I have here some tables of experiments, made by Mr. Kirkaldy, with reference to this particular subject, and which will be illustrative of what I have said. These experiments were made by Mr. Kirkaldy with lime of the same description, treated in the ordinary way, and by the selenitic process; and when I say that Mr. Kirkaldy made the experiments, everybody knows they must have been made with all the accuracy and care of which man is capable. He finds that, submitted to a thrusting stress with mortar compounded of an average of one of lime to three of sand, the mean resistance was on the square inch 121·7 lbs. Treated by the selenitic system, and gauged in the same way as the common lime mortar, but with five parts of sand on the average instead of three parts, the resistance increased from 121·7 lbs. on the square inch to 284 lbs. on the square inch; that is the selenitic process with nearly double the proportion of sand, at the same time doubled the resistance. When, however, the specimens of selenitic mortar were subjected to slight pressure, this pressure combined with the selenitic action, increased the resistance from 284 lbs. to the square inch to 629 lbs. to the square inch. Then, again, when subjected to a pulling stress, it was found that ordinary mortar gave 7·6 lbs. per square inch, and the selenitic process, with nearly double the quantity of sand, *i.e.*, with five parts instead of three, gave 16·6 lbs. per square inch. Against a pulling stress, by another mode of trial, the common mortar gave a resistance of 23 lbs. per square inch, and with the selenitic process it was increased to 63 lbs. per square inch (five parts of sand instead of three being, as before, employed in the selenitic specimens), and when pressure was applied with the trowel the 63 lbs. was increased to 83. These results will fairly explain the results Professor Westmacott obtained with a mixture of chalk and slaked lime, without going into the theory of the passage of carbonic acid gas from the one to the other. I may mention another case in which extraordinary resistance was obtained from

common lime by making experiments with mortar joints subjected to pressure; I allude to the experiments made in America, of "Smithfield" and other fat limes by the American Engineer General Totten. These experiments are to be found in his translation of Treussart's work.

CAPTAIN SEDDON.—I came into the room too late to hear all the remarks of Major-General Scott with regard to that portion of my paper in which I referred to the selenitic mortar. What I have said on that subject has been gathered from the little opportunity I have had of seeing the practical working of it, and no doubt Major-General Scott will be able to explain the point I discussed with regard to the large admixture of sand with the mortar. I have merely stated the results of the practical use of this mortar at Chatham, where we had nothing but our own judgment to guide us; and all I can say with regard to the proportion of six of sand to one of lime the contractor's foremen were perfectly contented with the ultimate hardness of the mortar. In a short time it attained a very much greater degree of hardness than could have been got from mortar made with any lime similar to the common Halling lime made use of. Possibly the objection to the use of so much sand may be got over. I am quite aware that workmen generally have a great objection to the use of any new material, and they will fight against it as long as they can, and bring forward all kinds of objections to it.

MAJOR-GENERAL SCOTT.—May I ask one question of Captain Seddon, and that is, whether, in the experiments he made, the mortar was mixed by hand or by mill? One can understand that with six parts of sand, imperfectly mixed by hand, you will get a short material; but it would be very different when worked with the mill for a very large job. At South Kensington we have done acres of plastering, and I never heard any complaint of the shortness of the material, but the mixing was always done with the mill. We tried some hand-mixed mortar, but the workmen very soon found it out.

CAPTAIN SEDDON.—I can hardly say they were experiments. In the building of the New Institute at Chatham the mortar was mixed in a mill, and my remarks are founded upon the results so obtained. The sand used was the Aylesford sand, which is a remarkably fine sand. I do not know whether that would have any effect.

Mr. T. MORRIS, Associate.—I understand that the use of this mortar was made by Captain Seddon in brick-work, whereas General Scott appears to have employed it principally for surface plastering.

CAPTAIN SEDDON.—It was used in the brick-work. On the face of the work the amount of sand used was reduced to four to one, which gave most satisfactory results.

MAJOR-GENERAL SCOTT.—There was no difference in the mortar we used, whether for brick-work or plaster.

Mr. JOHN P. SEDDON, Fellow.—Having used this kind of mortar, principally for plastering, I may state that some objection was made to it at first as being too short. A good deal of debris of freestone and other material about the place had been used instead of sand, and that, perhaps, was rather a sharp test, but it was not till we mixed a considerable quantity of hair with it that we got rid of the complaint of shortness. I may add that the work, on its completion, gave me great satisfaction; but I was charged an extra price for this plastering in consequence of the expense of the engine requisite to make it. Probably there should have been a saving in the cost of materials to set against this, but builders are often not as ready to give credit for omissions as they are to claim for anything in the shape of extras.

Mr. DINES, Visitor.—I am sorry I have not had an opportunity of looking into this paper as I could have wished, but there are one or two points I would refer to. It is stated here that green timber has not more than half the strength of dry. This is contrary to what I should have expected, and to the best of my recollection Barlow, in his essay on the strength of timber, states that wood is strongest when

green, giving as a reason that part of the load is expended in forcing the moisture out of the pores of the wood. I would ask Captain Seddon what is meant in his paper by "elastic limits." Tredgold supposed that no permanent set would take place in iron unless the load was something considerable, and that it might be safely loaded up to its elastic limit. But in all the building materials I have tried (glass excepted) a permanent set took place when the load did not exceed a tenth part of the breaking weight. Glass I found to be perfectly elastic, but this was contrary to the opinion of the late Professor Hodgkinson, who assured me he had noticed a set in glass by placing a lighted candle behind the bar upon which he experimented. With regard to small bars attached to large castings, I do not think it is a good method to arrive at the strength of a large casting; the metal that would be strongest in a small bar would not be the best mixture for a large casting. I can corroborate what is stated in the paper as to the uselessness of testing girders for a permanent set. When you have once taken the set out of a girder you may load it as often as you like up to the same weight without showing any additional set. I have always found tie-rods to break at the nut, and it is my habit to make the thread end of the rod a quarter of an inch larger than the other parts, in order to get the greatest strength out of the same material.

With regard to Corsham stone it is considered by some as fit only for indoor work; it is a bad stone to work in winter, but I have used a great deal of it for outdoor work, and it has stood well. Only a few days back I was at the Bath stone quarries with Mr. Randall, a person of great experience, and on looking at the different buildings in the neighbourhood, and discussing of what stone they had been built, he expressed to me his opinion that Corsham was the most durable of any. I prefer the Box Ground stone.

With regard to the strength of columns we know very little about it. I have always felt safe in using cast iron, as a column before it became weak would be very offensive to the eye. The only conclusion I have come to from my experiments upon stone is that if a column of one foot area will carry twenty tons, double that area will carry forty tons. The old rules gave the strength of columns as the fourth power of the diameter, and inversely as the square of the length. Hodgkinson used a fractional index 3·6 instead of 4, so that if you could not find the size wanted in his table logarithms were required to get at the strength. We really know very little of what wood or stone columns would carry at different lengths. Experiments well made are good for all times, but they are rather costly, and require great care to make them of any use.

CAPTAIN SEDDON.—With regard to the relative strength of dry and wet timber, and of iron and stone, the point of my paper has been to try to show that we do not know as much about stone as we ought, therefore I do not think there is much use in referring to what old authors have said upon the subject, especially where they differ in opinion. With regard to Corsham stone I have said, "If quarried in the spring of the year, and stacked at open order during the summer weather, it is doubtful whether Corsham stone is not well able to resist the weather." I think I shall be borne out in saying it is generally considered only fit for indoor work; at the same time, I belive it is capable of resisting the weather if it is quarried at the proper time of the year, and if it is not put into the work green when winter is coming on.

With regard to the "elastic limit," members of this Institute cannot do better than watch the experiments carried out by Mr. Kirkaldy, where the needle of dial indicator attached to the machine shows by its action a sudden start where the elastic limit occurs. What I mean by the "elastic limit" is the point beyond which a sensible permanent set occurs, or where the permanent set begins to increase rapidly at a greater ratio than the increase of force applied to the material. No doubt it is true that some permanent set occurs before you get to the elastic limit of the metal, but beyond that

point there is a very sensible increase of permanent set, no longer following the law of "*ut extensio sic vis.*" It goes on increasing at a very rapid rate, which is not the case before the material is strained beyond its elastic limit.

Professor KERR.—The most important result of the paper laid before us is I think likely to be damaged by the desponding view which the last speaker has taken of the subject. It appears as if he has said that we are very much in the dark with respect to the strength of materials altogether. I do not myself think so. We have before us the very important fact that Mr. Kirkaldy is now in a position to dispense with these unreliable experiments upon small model pieces, and has commenced a system which I hope he may be able to continue, of experimenting upon beams and pillars of full size. Now if Mr. Kirkaldy can go on in that good path I think we are in a fair way to know a good deal about the strength of materials. But even at present we know almost enough for architects if not for engineers. We know pretty well what is the crushing weight of various building stones, and also what pressure brick work will sustain; of course, whenever our materials give way by crushing strain, it is generally from some defect in the strength of the material at the base of the wall. If you can tell us what strain a single brick will stand, we can tell the height of brick work we can rely upon; with respect to timber also, I hope Mr. Dines will not lead us to suppose that our knowledge of the rules of strain with regard to timber is to be entirely ignored.

Mr. DINES.—Not the rules, but the different qualities of timber.

Professor KERR.—No doubt: we know that hidden flaws occur in timber and in cast iron, but we are nevertheless in a position to calculate very closely what may be expected of the average of either of those materials of a given structure. I would at any rate beg leave to ask Mr. Kirkaldy what precise position he is in with regard to continuing his experiments upon materials at full size.

Mr. DAWSON, Fellow.—That is rather a delicate question to put to Mr. Kirkaldy. I was present at Mr. Kirkaldy's works on Saturday last, and I am only sorry there were so few members of the profession who responded to that gentleman's invitation, but during an hour and a half I saw what I am sure would have gratified members if they had been there. One experiment was made upon a column of "green-heart" timber which showed very accurately what Capt. Seddon has just stated. Up to a certain point of pressure, viz: about 200,000 lbs. per square inch upon the end of the column, the set when the load was removed was trifling, but afterwards upon each small addition to the above pressure being applied, the set increased in an enormous ratio. The fact was made undeniably clear by this machinery; and I think it comes to this point: if we are to get the benefit of these numerous experiments (and this was one of a large series made by Mr. Kirkaldy for an engineer in Liverpool with respect to the use of "green-heart" timber in docks) it is necessary that our Institute should take up the matter in some practical way. There should be carried out a series of experiments with timber, wrought and cast iron, stones of various kinds, and in fact all the chief building materials. There are for instance some stones which have hitherto been almost unknown in London, and about which I have found a remarkable degree of prejudice, but they are really valuable stones, and when tested they have proved themselves to be of much greater strength than had been attributed to them. I should like to see this subject taken up by the Institute and treated as a matter of business, so that we may derive the benefit of valuable experiments made by the truthful machinery of Mr. Kirkaldy upon these different materials.* We should have a correct basis to go upon, which would be of the utmost value. We know the difference there is in the formulæ of the various reference books, and at times one is amazed to find how little they are to be depended upon.

MR. E. NASH, Fellow.—With regard to the tensile power of iron I think it is pretty well known

* A Committee on "Building Materials and Construction" has been appointed by the Council of the Institute, n d will for the future give attention to such investigations as are referred to in Mr. Dawson's proposal.

that all metals of a crystalline nature have a tendency, after they have been forced out of their natural condition by artificial treatment, to go back to their former state; and if that be so the tensile strength of wrought iron will gradually diminish with age. Concussion will also assist the process; and I have heard it stated that a wrought iron bar dropped from a height upon a hard material will thus lose much of its tensile power, and be aided in its endeavour to go back into its normal granular condition. Copper wire becomes absolutely rotten by age, and I believe it to be much the same with iron wire, and even with other wrought iron, and thus (the endurance of tensile strength being evanescent) wrought iron structures will eventually fall, simply from the fact of becoming by age either rotten or deficient in tensile power.

Mr. KIRKALDY, Visitor, briefly expressed his readiness to devote himself and the machinery, which he had erected at considerable cost, to the carrying out of any testing experiments with which he might be entrusted. The means of doing so, he said, were at hand to any extent and in any variety that might be required, and it remained for those who were about to engage in large works to satisfy themselves upon any points with respect to the strength of materials concerning which they at present entertained any doubts.

THE PRESIDENT, in closing the discussion, said,—No one can question for a moment the great benefits that are presented by Mr. Kirkaldy's valuable system of testing the strength of materials. The paper of Captain Seddon is full of scientific and interesting matter, and what we have heard to-night is of an interesting and practical nature. The paper has been printed *in extenso* and circulated amongst the members, and I have no doubt we shall all profit by its careful perusal and consideration. To that gentleman I am sure are due the special thanks of the meeting for the great care and time he has given to the preparation of this very elaborate communication. Our thanks are also due to Mr. Kirkaldy, whose experiments have completely supported the views put forward in the paper. I regret I was not able to be present on Saturday, but I hope to avail myself of his kindness on a future occasion. I may state, as bearing upon some of the remarks made to-night, that we have recently formed a committee upon the very subject of testing materials, and I think the suggestions that have been made on that subject will be very fairly met by that committee. Our thanks are also especially due to Major-General Scott for his valuable remarks upon the selenitic process, and they have completely satisfied me that the difficulties I have hitherto felt with regard to it have no foundation.

The vote of thanks was unanimously agreed to, and the meeting adjourned.